I-ERA

THE JOURNAL OF Agricultural Economics Research

United States
Department of
Agriculture

Economic
Research
Service

Articles

Book Reviews

Vol. 42, No. 3, 1990

This periodical is published quarterly. Subscription rates are: 1 year, $8; 2 years, $15; 3 years, $21. Non-U.S. orders, please add 25 percent. Send check or money order (payable to ERS-NASS) to:
ERS-NASS
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Rockville, MD 20849-1608
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The Secretary of Agriculture has determined that the publication of this periodical is necessary in the transaction of public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director, Office of Management and Budget.

Contents

In This Issue

First, a word about the Journal's series of essays. The editors and editorial board of JAER thought a journal devoted largely to designing, building, and polishing the intellectual furniture of agricultural economics should give some attention to the effect of that furniture on the posture of the profession. So we began with an essay on the product of the profession, publishing. It was followed by six essays appraising agricultural economics and examining methodological and philosophical issues pertaining to research. The philosophical progression culminated in an essay on economics and ethics.

In this issue, we return from the sublime to the meticulous with Hertel's essay on computable general equilibrium. He argues that the problems of model specification, parameter choice, disaggregation, and policy representation in general equilibrium are similar to those of partial equilibrium analysis. He compares partial and general equilibrium with an extremely reduced-form analysis of a farm subsidy program. From this illustration, he argues that general equilibrium models can be practical, need not be complex, and are compatible with partial equilibrium solutions to specific problems. He concludes that widespread familiarity with general equilibrium models will enable the body of agricultural economists to focus disparate research findings on a single economic problem.

Kim and Lin examine the economic impacts of a trade liberalization policy in the world wheat market. They employ an export-side international trade model, Armington and spatial equilibrium, on 23 countries (some are country composites). As policy interventions, they extracted producer subsidy equivalents and consumer subsidy equivalents. Results of their analysis show European Community and Canadian exports declining, the American, Argentine, and Australian exports increasing. There are economic gains for all exporting countries.

Trade issues closer to home, specifically at the community level, are discussed in the Henderson article. He examines 79 rural Minnesota communities to determine the relation between size of community and types of retail business. He bases his inquiry of different business functions on central place theory. Improved transportation, advanced marketing, and increased income tend to favor retailing in larger communities over smaller communities.

Szmedra, Wetzstein, and McClendon analyzed the use of integrated pest management technologies on soybeans and concluded that prior technologies, as well as risk response, influenced the adoption of the technology. They used several criteria that gave mixed results for total and partial adoption on dryland, but uniformly favored partial adoption on irrigated land. They conclude that riskiness is not the overriding factor in the adoption of IPM.

Book reviews include Letson's evaluation of *Benefit-Cost Analysis: A Political Economy Approach* by Schmid. Letson is generally complimentary of Schmid's efforts to combine standard benefit-cost techniques with budgetary politics. He feels, however, that Schmid is less successful in bridging analysis and political action than he is at identifying the need for the bridge. He nevertheless recommends Schmid's book, perhaps as a companion to Mishan's fourth edition on benefit-cost analysis.

Anderson reviews *Transformation of International Agricultural Research and Development* edited by Compton. Here is a good book to introduce agricultural research and technology transfer to readers not already thoroughly versed in the subject. The underlying theme of the book is the "seemingly obvious point" that for technology to be created and adopted, it should meet the needs of users.

Lee critiques *Frontiers of Input-output Analysis* by Miller, Polenske, and Rose, one more volume in the evolution and extension of the basic I/O model. Despite the brevity of many of the large number of articles in this compilation, hence the need to look elsewhere for details, Lee rates the volume as a significant addition to I/O literature.

Percy endorses Boyd and Hyde's *Forestry Sector Intervention: The Impacts of Public Regulation on Social Welfare* while injecting his own preference for including among the case studies the subject of welfare effects of trade barriers on forest products. Percy writes from Edmonton, not Tokyo. He compliments the authors on the quality of analysis and careful treatment of the seven case studies. The case studies support the central proposition of the book that policy interventions to correct market failures can make matters worse.

We receive many more books and announcements of books than we can ever hope to review within the space available in the Journal. Selections are intended to call attention to useful publications across a wide spectrum of interests of social science in agriculture,

rural affairs, and natural resources. Occasionally, but just occasionally, we will do a fringe piece if we think it might stoke the interest of Journal readers. We invite suggestions on our policy as well as on specific books you think might serve the readers. Books and their reviews are an important dimension of the Journal, and we hope you will contribute to their selection and review.

Gene Wunderlich

General Equilibrium Analysis of U.S. Agriculture: What Does It Contribute?

Thomas W. Hertel

Applied general equilibrium analysis as we know it today has intellectual origins in the debate over the feasibility of the centralized computation of a Pareto optimal allocation of resources within an economy (Whalley, pp. 30-34).[1] During the first half of the century, economists were preoccupied with the question of whether or not it was computationally feasible to solve the associated system of behavioral equations. Recent developments in operations research have proven optimists correct. It is indeed possible to solve very large models representing national economies, either in the form of centralized planning problems or, more commonly, as decentralized equilibrium problems. While this has not brought an end to the debate over the operational relevance of general equilibrium theory, the increasing use of computable general equilibrium (CGE) models in policy analysis has served to sharpen the debate. It now focuses heavily on questions such as model specification, parameter choice, disaggregation, and the appropriate representation of policies (Whalley). CGE analysis now has a great deal in common with partial equilibrium modeling, a theme I will develop in this essay.

Leif Johansen implemented the first operational CGE model in the late 1950's. Variants of this model are still used for planning purposes in Norway (Shreiner and Larsen). These models have also been popular in the development economics literature (Robinson, 1988, 1989). CGE analysis in North America has tended to emphasize tax and trade issues (Shoven and Whalley). One consequence is that the U.S. Department of Treasury and the Canadian Department of Finance both have employed variants of these models for a number of years. However, nowhere has CGE analysis been as successfully institutionalized as in the Australian Industries Assistance Commission (Powell and Lawson; Vincent), where it has been used for 15 years to analyze the economywide effects of changing relative rates of protection.

In light of this history, the relatively recent appearance of CGE analysis in U.S. agricultural economics may be viewed as a belated arrival. But, perhaps, there is good reason for this. A general equilibrium model is only as strong as its partial equilibrium components, and, until recently, most CGE models had fairly simple representations of producer and consumer behavior. Thus, further acceptance of CGE models applied to U.S. agriculture hinges on better communication between the modelers and other agricultural economists aimed at strengthening critical components of the models. Unfortunately, partial equilibrium analysts who do not understand CGE models cannot improve them.

This essay attempts to bridge the gap between partial and general equilibrium analysts, thus promoting greater dialogue between practitioners of CGE analysis and others in the profession. Along the way, I hope to dispel several misperceptions of CGE analysis. For example, CGE analyses are often viewed as abstract, theoretical exercises, with little resemblance to partial equilibrium modeling, much less to the real world. While some CGE applications may fall prey to this criticism, there is no inherent reason why this must be the case. To show the similarities between the partial and general equilibrium approaches, I will begin by comparing partial and general equilibrium analyses of a subsidy on farm output. Similarities and differences as well as strengths and weaknesses of the two methodologies will be identified.

Partial Equilibrium Analysis of a Farm Subsidy

Partial equilibrium models may be thought of as collections of supply and demand equations, representing a summary of economic behavior in various markets of interest. Since agricultural economists are often concerned with farm commodity markets, the supply equations in many models describe the supply of products from the farm sector, while the demand equations describe the market conditions facing producers beyond the farmgate. Depending on the particular biases of the researchers, these supply and demand equations may or may not be derived from explicit assumptions about producer and consumer behavior. Let's leave that issue aside for the moment and turn to the implications of this framework for analyzing a farm subsidy.

I will simplify by assuming that the intervention in question may be expressed as an *ad valorem* output subsidy. (More complex policies do not shed any light on the distinction between partial and general equilibrium analyses.) In this case, the relationship between the farm price of output (p_F) and the market price (p_H)

Hertel is associate professor in the Department of Agricultural Economics, Purdue University, West Lafayette, IN. Otto Doering, Garth Holloway, Everett Peterson, Marinos Tsigas, and Wally Tyner provided helpful comments on an earlier draft. Earlier versions have been presented in seminars at Purdue University, USDA's Economic Research Service, and the University of Missouri. The research discussed here was conducted under a project jointly funded by the Economic Research Service and the Agricultural Experiment Station, Purdue University.

[1]Sources cited in the text are listed in the References section at the end of this essay.

is simply $p_F = s * p_H$, where $s > 1$ denotes the presence of a subsidy. The partial equilibrium solution to this problem, written in terms of the supply and demand elasticities, becomes:

$$\hat{p}_H = (\eta_F - \eta_H)^{-1} \eta_F(-\hat{s}), \tag{1}$$

where "ˆ" denotes proportional change. In the case of a single commodity, η_F and η_H are the relevant supply and demand elasticities, so that we may verify the familiar special cases whereby: (a) either perfectly elastic demand ($\eta_H = -\infty$) or inelastic supply ($\eta_F = 0$) results in the subsidy benefits going entirely to farmers, while (b) either perfectly elastic supply ($\eta_F = \infty$) or inelastic demand ($\eta_H = 0$) results in all of the subsidy benefits being passed on to consumers. In the multiple-commodity case, s is a vector of interventions, and η_F and η_H are elasticity matrices, with as many dimensions as there are markets in the model.

This multicommodity, partial equilibrium framework is adequate for many, if not most, applications. However, there are some important gaps to keep in mind. A first limitation of expression 1 is its failure to acknowledge the finite resource base in the economy. To the extent that the farm subsidy encourages resources to move into agriculture (or perhaps it discourages them from moving out), the rest of the economy has less land, labor, and capital to work with. There is an opportunity cost associated with this factor movement that is only superficially acknowledged by the introduction of upward sloping factor supply schedules into a partial equilibrium model of the farm sector.[2]

A second limitation of the partial equilibrium model is its failure to address the question: Who foots the bill for the added subsidies? The opportunity cost of raising 1 dollar of additional revenue via the current system of Federal income taxes has been shown to be considerably more than a dollar, due to the marginal excess burden associated with further distortions in consumer and producer choices (Ballard; Shoven and Whalley). By contrast, this phenomenon may be explicitly dealt with in a CGE model. Even if an economywide model does not flesh out the tax system, it is possible at least to keep track of the transfers implicit in a given subsidy.

The third weakness of the partial equilibrium model is the absence of an explicit budget constraint for the household(s) in question. There is no link between the sources and the uses of income. Changes in factor returns are not reflected in altered consumer expenditures. This limitation is most severe when the policy shocks considered are very large, and when they result in income transfers between households with very different consumption patterns.

A final limitation of the partial equilibrium approach is the absence of any definitive check on the conceptual and computational consistency of this model. The larger and more complex the model, the greater the probability of inconsistencies. This leads to skepticism on the part of model users and potential "consumers" of model results. By contrast, as will be pointed out below, Walras' Law offers a powerful check on the consistency of a well-defined general equilibrium model. In fact, this alone may be reason enough to justify the CGE approach in some cases.

General Equilibrium Analyses of a Subsidy

To illustrate how the general equilibrium approach addresses these limitations, it is necessary to lay out the structure of a very simple CGE model. Because the model is only complex enough to illustrate my basic point, it can be completely described by one picture (fig. 1).

A Simple Model

I have assumed a closed economy, with one aggregate household which consumes two goods: food (good #1) and nonfood (good #2). This household also owns all primary factors of production in the economy, which are held in fixed supply ($\bar{q}_{H0}$ and $\bar{q}_{H3}$). Again, for the sake of simplicity, I distinguish between only two primary factors: farmland (good #0), which is specific to the farm and food sector, and a capital/labor aggregate (good #3), which is mobile between the two sectors. Household income ($y = p_{H0}\bar{q}_{H0} + p_{H3}\bar{q}_{H3}$) is derived from these primary factors. Given the initial household budget shares, $c_{H1}y$ is spent on good #1 and $c_{H2}y$ is spent on good #2.

There are no intermediate inputs in this economy, and constant returns to scale in production are assumed. The nonfood commodity is produced using only the capital/labor input, while the farm and food commodity is produced by combining the capital/labor input with farmland. (In a sense, this is what distinguishes the farm economy from other sectors.) In initial equilibrium, the cost shares of each of the two inputs are given by c^1_{F0} and c^1_{F3}. The land and nonland inputs are substitutable in food production, with the ease of substitution determined by the non-negative elasticity σ_F. This substitutability, in fact, underpins the food sector's partial equilibrium supply response in this model, which may be expressed as:

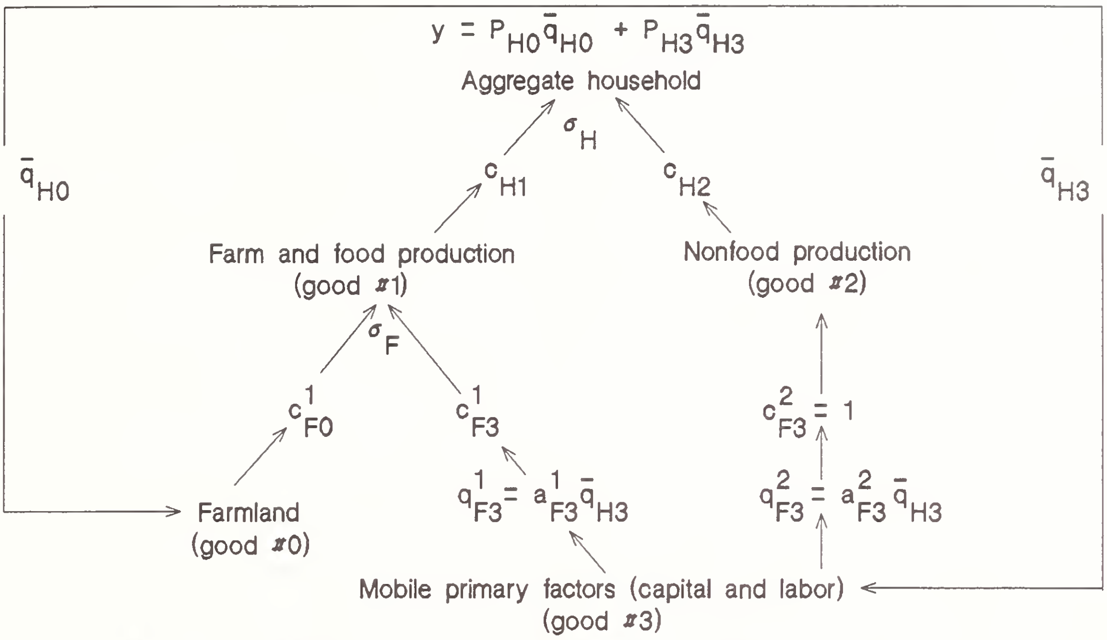
$$\eta_F = \sigma_F(c^1_{F3}/c^1_{F0}). \tag{2}$$

Note that supply response increases with increased substitutability for the fixed land input, and with an increased share of variable inputs in total costs (c^1_{F3}).

[2]See Floyd for an early illustration of this type of partial equilibrium model.

Figure 1

An illustrative general equilibrium model with four goods, one household, and two productive sectors[1,2]



1/ Subscripts H and F refer to the household and firms, respectively. Each of these entities may face different prices for the four goods, which are indexed by using subscripts 0 to 4. Superscripts 1 and 2 refer to (1) the farm and food sector and (2) the nonfood sector. $\bar{q}_{H0}$ and $\bar{q}_{H3}$ represent the fixed supplies of land and nonland inputs which earn returns of P_{H0} and P_{H3}. c^1_{F0} denotes the cost share of good #0 (land) in sector 1, with similar definitions for c^1_{F3}, c^2_{F3}, c_{H1}, and c_{H2}. $a^j_{F3} = q^j_{H3}/\bar{q}_{H3}$, which is the quantity share of this input in sector j.

2/ Each arrow corresponds to an equation in the model. A complete set of equations, along with their manipulation and solution, is available from the author.

The importance of comparing supply elasticities across models is rarely lost on partial equilibrium analysts; however, general equilibrium modelers are less diligent in this matter. This is probably because η_F does not enter directly as a parameter in the model, but must instead be calculated as in equation 2.[3] Based on my own experience, differing assumptions about partial equilibrium behavior go a long way toward explaining empirical discrepancies between partial and general equilibrium models. Many differences between such analyses are falsely attributed to "general equilibrium" effects. Consequently, I encourage partial equilibrium modelers and other consumers of CGE results to demand this type of summary information from CGE modelers.

A final point regarding figure 1 stems from the fact that we need a convenient method of summarizing the two sectors' relative claims on the mobile factor of production. This may be done by defining $a^1_{F3} = q^1_{F3}/q_{H3}$, that is, the quantity share of the capital/labor aggregate which is used in agricultural production. Similarly, $a^2_{F3} = q^2_{F3}/q_{H3}$.

[3]See Hertel (1989) for a general discussion of how to compute partial equilibrium supply elasticities under alternative assumptions about technology and factor mobility.

Introducing a Farm Subsidy

Having laid out the basic notation for this model, we are in a position to solve it. This involves collapsing the equations implicit in figure 1 into as many dimensions as there are commodities. In this sense, finding a solution is no different than in the partial equilibrium case, with one important distinction. Since the general equilibrium model is exhaustive in its treatment of economic activity, one of the market-clearing conditions is redundant. This is Walras' Law, which has two important practical implications for CGE analysis. First, since we are left with only three equations, we can solve only for the changes in relative prices among the four commodities. Here, I will choose land as the numeraire good and will omit the supply = demand equation for land, which will produce the following outcome after introduction of a farm subsidy:

$$\hat{p}_H^* = \begin{bmatrix} p_{H1}/p_{H0} \\ p_{H2}/p_{H0} \\ p_{H3}/p_{H0} \end{bmatrix} = \begin{bmatrix} 1 + (c^1_{F3}x) \\ c^2_{F3}x \\ x \end{bmatrix} (-\hat{s}), \qquad (3)$$

$$\text{where } x = \frac{(a^1_{F3}c_{H2} - a^2_{F3}c_{H1})\,\sigma_H}{-a^1_{F3}c^1_{F0}\sigma_F - (a^1_{F3}c_{H2} - a^2_{F3}c_{H1})\,(c^1_{F3} - c^2_{F3})\,\sigma_H}.$$

The second practical implication of Walras' Law is that if we evaluate changes in supply and demand in the omitted land market, using the equilibrium relative price changes, they must be equal, that is, $\hat{q}_{H0}(\hat{p}_H{}^*) = \hat{q}_{F0}(\hat{p}_H{}^*)$. Since this property is an implication of the entire model's structure, its verification offers a global check on the conceptual and computational consistency of this model. This can be extremely valuable. By way of example, consider what might happen in a large nonlinear model with hundreds of markets when a new wrinkle such as imperfect competition is introduced. What if the modeler forgets to distribute to households the excess profits generated in the new equilibrium? How could we possibly know that this has been omitted? There is no general method of checking for such overlooked inconsistencies in a partial equilibrium model. However, in a general equilibrium model, such a leakage would result in insufficient commodity demand, and hence, insufficient derived demand for land. Consequently, Walras' Law would be violated.

Now return to expression 3. Note that each of the relative price changes depends on the common parameter "x." This parameter is actually quite similar in structure to the ratio of elasticities premultiplying the farm subsidy in expression 1. To see this, note that (given c_{Fj} and c_{Hj}) σ_F determines η_F and σ_H determines η_H. Thus, the value of x, and the subsequent degree to which this subsidy is shifted among markets, depends fundamentally on the supply and demand elasticities embedded in this model. When $\sigma_H = 0$, such that demands are not responsive to price, or $\sigma_F = \infty$, such that the partial equilibrium farm supply curve is perfectly elastic, $x = 0$ and all benefits from the subsidy are passed forward to consumers. This is the same result we encountered in the partial equilibrium case. By contrast, if nonland inputs cannot be substituted for the sector-specific land input ($\sigma_F = 0$), then farm supply will be completely unresponsive to price, and x may be shown to collapse to $x = (c^1_{F0})^{-1}$, which means that all of the subsidy benefits are passed back to landowners.[4] This confirms our partial equilibrium intuition.

We can also see how, in the more general case, all the parameters in the model have a bearing on the general equilibrium outcome.[5] Note, however, what happens when the farm sector becomes "small" relative to the rest of the economy. The value of a^1_{F3} approaches zero, and we can obtain approximate relative price changes for the farm sector without reference to the nonfarm economy:

$$(\hat{p}_{H1}/\hat{p}_{H0}) \cong [1 + (c^1_{F3}/c^1_{F0})]\,(-\hat{s}), \text{ and}$$

$$(\hat{p}_{H3}/\hat{p}_{H0}) \cong [1/c^1_{F0}]\,(-\hat{s}). \qquad (4)$$

This is a formal demonstration of why we do not need a general equilibrium model to assess accurately the farm sector impact of most farm policy changes in the case of a highly industrialized economy such as the United States. This point likely comes as little surprise to many economists. Since just 2-3 percent of the U.S. labor force is involved in farming, why model the entire economy to say something about the agricultural impact of a grain subsidy?

Three Common Myths Dispelled

At this point, I hope that I have clarified several popular misconceptions about CGE modeling. The first myth is that general equilibrium analysis is an abstract, theoretical exercise. However, applied work in this area boils down to a problem of constructing a sound data set and choosing (or estimating) appropriate elasticities. This is hardly a theoretical exercise, and it is really no different from partial equilibrium modeling.

A second myth is that CGE models are complex and difficult to solve. In fact, the solution of CGE models is not necessarily any more complex than the solution of large, nonlinear partial equilibrium modes. Matrix inversion is sufficient to solve a locally linearized CGE model. And the solution of well-specified nonlinear CGE models can generally be accomplished by choosing from a variety of software alternatives. For large models, the CGE approach has the great advantage of having a global consistency check, namely Walras' Law.

The third myth relates to the value of indiscriminate applications of CGE analysis to issues facing U.S. agriculture. For example, if we can conduct CGE analyses of mandatory supply control, then why not look at more specific issues like the tobacco program? Again, if one is interested only in how a farm policy intervention influences the farm sector itself, then partial equilibrium analysis is probably good enough. Rather than investing scarce time and money in developing (or modifying) a CGE model, it may be much wiser to devote research resources to the improvement of partial equilibrium analyses.

I imagine the reader is now wondering: What's the big deal? Why all of the fuss about CGE analysis of the farm and food economy? Keep reading—the next section discusses why such efforts are warranted.

[4]The magnification factor, $(c^1_{F0})^{-1} > 1$, serves to load a given amount of subsidies onto the smaller land expenditure base.

[5]The reader might wonder why income elasticities of demand do not appear in expression 3. Since the economy in figure 1 is closed (that is, there is no international trade), and with fixed factor supplies, the only way disposable income can change is through a change in the efficiency with which the fixed resource base is employed. Such changes are commonly referred to as changes in "excess burden." In this context, I have assumed the economy in figure 1 to be initially in an undistorted state, where firms and households face the same prices ($p_{Hn} = p^1_{Fn} = p^2_{Fn}$ for all n) prior to introduction of the subsidy. This means that, to a first order approximation, marginal changes in the farm subsidy will not have excess burden effects. Since there is no change in excess burden, then there will be no change in household income. This is why income elasticities of demand do not appear in the solution.

Benefits From Using CGE Analysis

Five good reasons exist for applying the CGE framework in selected analyses of U.S. agriculture:[6]

Accounting consistency
The treatment of interindustry effects
Theoretical consistency
CGE analysis as a vehicle for "putting things in perspective"
Welfare analysis

Those who have worked with such models quickly recognize that the accounting identities in a CGE model are as important as the behavioral equations. The fact that: (a) households cannot spend more than they earn, (b) the same unit of labor cannot be simultaneously employed in two different places, and (c) the economy as a whole must balance its payments with the rest of the world, serves to circumscribe the range of possible general equilibrium outcomes. CGE models are built upon a social accounting matrix (SAM) which details all the basic identities for a given economy (Pyatt and Round, Hanson and Robinson). Thus, the first advantage of CGE analysis revolves around the explicit incorporation of these accounting identities into the behavior model.

A second advantage of CGE analysis arises from tracing and measuring interindustry linkages between the farm and nonfarm sectors. When conducting a partial equilibrium analysis, it is often very difficult to know where to "draw the line," because the farm sector purchases inputs from the manufacturing, mining, and service sectors, and farm output is sold to both food and nonfood sectors. Having an exhaustive model for analyzing such issues is valuable.[7]

Theoretical consistency is particularly important in large economic models, which too often become black boxes, unintelligible, even to other modelers. Unless individual components are built upon received economic theory, other researchers have great difficulty interpreting model results. If the model structure adheres strictly to standard neoclassical theory, as do well-specified CGE models, the model user can draw upon experience to understand and explain what is going on when a given policy is changed. A final advantage of theoretical consistency, which has already been mentioned, is that Walras' Law may be used as a global consistency check.

Another advantage of CGE analysis is that it helps to put things in perspective. Microeconomic theory emphasizes the importance of relative, as opposed to absolute, levels of economic variables. How taxation or technological change affects the farm sector is largely irrelevant unless we know how the levels of these variables compare with those in the nonfarm sector. For example, taxation of the farm and food sector reduces farm output when viewed in isolation. However, a general equilibrium analysis of U.S. tax policy reveals that low relative rates of taxation have conferred an implicit subsidy on agriculture which at times has rivaled direct farm payments in overall importance (Hertel and Tsigas).[8]

Finally, one of the things I like best about CGE models is the fact that they force us to focus more clearly on households, and, ultimately, on people. Changes in welfare are measured by examining the change in household utility, or the implied changes in real income (adjusted for all price changes). The latter is much more concrete, in my opinion, than the concepts of producer and consumer surplus, and emphasizes, for example, that farmers are consumers and taxpayers as well as owners of agricultural assets.

Conclusions

In an attempt to catch up with three decades of applied general equilibrium analysis, U.S. agricultural economists have recently risked overdoing CGE modeling. We may have oversold the benefits of CGE modeling, while failing to acknowledge many of limitations.

Yet, there remain areas of use for CGE models in agricultural economics which have not been pursued with sufficient vigor. One of these is integrating diverse research results and bringing them to bear on specific policy problems. Where else can the work of a production economist be integrated with that of someone estimating complete consumer demand systems?[9] Many research results in international trade, industrial organization, and marketing may also be integrated into a CGE framework. This makes it possible to distinguish between (a) parameters that we either already know a lot about or which are unimportant for current policy issues, and (b) parameters about which we know relatively little but which are key to the accurate assessment of important policies. The implications of such model-sensitivity analyses for directing future policy-oriented research should not be overlooked.

CGE analysis has also received far too little attention in the training of graduate students. Too many Ph.D. agricultural economists graduate without acquiring an economywide perspective on agricultural problems.

[6]See Hertel (1990) for a survey of CGE applications relating to agriculture.

[7]Input-output analysis has been the preferred vehicle for assessing interindustry linkages. CGE analysis simply permits us to relax the customary assumptions of fixed I-O coefficients, perfectly elastic factor supplies, and exogenous final demand. In this sense, I-O analysis is a special case of CGE analysis.

[8]See also Boyd, and Boyd and Newman for further analysis of tax policy and U.S. agriculture within an economywide setting.

[9]See Hertel, Ball, Huang, and Tsigas for an illustration of this point.

They often lack the ability to see how their specialized knowledge of production, consumption, marketing, and trade fits together and how these diverse pieces interact in determining the incidence of shocks to the farm and food system.[10]

In summary, CGE analysis is a valuable addition to the agricultural economist's analytical tool kit. However, a CGE model is only as good as its individual components. Robert Solow made this same point in his critique of Jay Forrester's global modeling efforts in the early 1970's. Forrester asserted that rather than "go to the bottom of a particular problem ... what we want to look at are the problems caused by interactions." To this, Solow (p. 157) responds:

> I don't know what you call people who believe they can be wrong about everything in particular, but expect to be lucky enough to get it right on the interactions. They may be descendants of the famous merchant Lapidus who said he lost money on every item he sold, but made it up on the volume.

Future improvements in the CGE analysis of U.S. agriculture depend on developments in the partial equilibrium specification of farm sector models. Thus, a great need for dialogue exists between those who are primarily involved in CGE modeling and those who conduct other sorts of farm sector analyses. However, such a dialogue can be fruitful only if CGE models are "demystified." It is my hope that this essay will help to further such debate within the agricultural economics profession.

References

Ballard, C.L., J.B. Shoven, and J. Whalley. 1985. "General Equilibrium Computations of the Marginal Welfare Costs of Taxes in the United States," *American Economic Review*. Vol. 75(1), pp. 128-38.

Boyd, R. 1988. *An Economic Model of Direct and Indirect Effects of Tax Reform on Agriculture*. Technical Bulletin No. 1743. U.S. Dept. Agr., Econ. Res. Serv.

Boyd, R., and D. Newman, 1990. "Tax Reform and Land Using Factors in the U.S. Economy: A General Equilibrium Analysis," *American Journal of Agricultural Economics* (forthcoming).

Hanson, K.A., and S. Robinson. 1988. "Data, Linkages, and Models: U.S. National Income and Product Accounts in the Framework of Social Accounting Matrix." Unpublished paper. U.S. Dept. Agr., Econ. Res. Serv.

Hertel, T.W. 1990. "Applied General Equilibrium Analysis of Agricultural Policies." Staff Paper No. 90-9. Dept. Agr. Econ., Purdue University, West Lafayette, IN.

Hertel, T.W. 1989. "Negotiating Reductions in Agricultural Support: Implications of Technology and Factor Mobility," *American Journal of Agricultural Economics*. Vol. 71(3).

Hertel, T.W., V.E. Ball, K.S. Huang, and M.E. Tsigas. 1989. *Computing General Equilibrium Farm Level Demand Elasticities for Agricultural Commodities*. AES Research Bulletin No. 988. Purdue University, West Lafayette, IN.

Hertel, T.W., and M.E. Tsigas. 1988. "Tax Policy and U.S. Agriculture: A General Equilibrium Analysis," *American Journal of Agricultural Economics*. Vol. 70(2), pp. 289-302.

Floyd, J.E. 1965. "The Effects of Farm Price Supports on the Returns to Land and Labor in Agriculture," *Journal of Political Economy*. Vol. 73, pp. 148-58.

Johansen, L. 1960. *A Multisectoral Model of Economic Growth*. Amsterdam: North-Holland Press. (Second, expanded edition: 1974).

Keller, W.J. 1980. *Tax Incidence: A General Equilibrium Approach*. Amsterdam: North Holland Press.

Powell, A.A., and T. Lawson. 1986. "A Decade of Applied General Equilibrium Modelling for Policy Work." Paper presented at the Third IIASA Task Force Meeting on Applied General Equilibrium Modelling, Laxenburg, Austria, August (revised November 1986).

Pyatt, G., and J.I. Round. 1979. "Accounting and Fixed-Price Multipliers in a Social Accounting Matrix Framework," *Economic Journal*. Vol. 89, pp. 850-73.

Robinson, S. 1988. "Multisectoral Models of Developing Countries: A Survey," *Handbook of Development Economics*. Chenery and Srinivasan (eds.). Amsterdam: North Holland Press.

__________. 1989. "Computable General Equilibrium Models of Developing Countries: Stretching the Neoclassical Paradigm." Working Paper No. 513. Dept. Agr. and Res. Econ., University of California.

Shoven, J.B., and J. Whalley. 1984. "Applied General Equilibrium Models of Taxation and International Trade," *Journal of Economic Literature*. Vol. 22, pp. 1,007-51.

[10]A copy of a syllabus for such a course at Purdue is available from the author. Write to: Thomas W. Hertel, Department of Agricultural Economics, Purdue University, West Lafayette, IN 47907.

Schreiner, P., and K.A. Larsen. 1985. "On the Introduction and Application of the MSG-Model in the Norwegian Planning System," *Production, Multisectoral Growth, and Planning*. Forsund, Hoel, and Longva (eds.). Amsterdam: North Holland Press.

Solow, R.M. 1973. "Is the End of the World at Hand?," *Challenge*. March-April issue.

Vincent, David P. 1986. "Applied General Equilibrium Modelling in the Australian Industries Assistance Commission: Perspectives of a Policy Analyst." Paper presented at the Third IIASA Task Force Meeting on Applied General Equilibrium Modelling, Laxenburg, Austria, August.

Whalley, J. 1986. "Hidden Challenges in Recent Applied General Equilibrium Exercises," *New Developments in Applied General Equilibrium Analysis*. Piggott and Whalley (eds.). New York: Cambridge University Press.

An Export-Side Armington Model and Trade Liberalization in the World Wheat Market

C.S. Kim and William Lin

Abstract. *This paper develops and applies an export-side international trade model to analyze economic gains resulting from trade liberalization in the world wheat market. Major policy variables in the analysis include the removal of producer and consumer subsidy equivalents in industrialized countries. Estimated gains are substantial for all exporting countries, ranging from \$5.32 million for Argentina to \$4.24 billion for the United States.*

Keywords: *Export-side international trade model, producer subsidy equivalent, consumer subsidy equivalent.*

Trade liberalization has become a major issue facing agricultural policymakers. One of the primary concerns of the past several decades, shared among grain-exporting countries, has been access to import markets. Today, circumstances have changed such that many grain-exporting countries are concerned not only with better access to markets but also with their own expansion in grain production associated with huge producer subsidies (*23*).[1] As a result, the United States and other members of the General Agreement on Tariffs and Trade (GATT) undertook the Uruguay Round of international trade negotiations in 1986, after the U.S. Congress passed the 1985 Food Security Act.

Since most countries have adopted different types of trade barriers and domestic farm policies (*13*), a common basis for multilateral trade negotiations must be identified. As a first step in generating this common basis, all tariff and nontariff trade barriers and domestic agricultural policies for major grain-trading countries were quantified in monetary terms by the Organization for Economic Cooperation and Development (OECD) and by the Economic Research Service (ERS). The concepts of producer subsidy equivalents (PSE's) and consumer subsidy equivalents (CSE's) were used to quantify the degree of protection by country and by commodity. The PSE is the level of subsidy that would be necessary to compensate producers associated with removing all government support under current farm programs. The CSE is the payment that would be necessary to compensate consumers upon removing all government support under current farm programs (*7*).

Even though PSE's and CSE's provide a common basis for determining the degree of trade protection, they may be insufficient as the basis for successful trade negotiation. To reach an agreement in multilateral trade negotiations, governments must be convinced that many of their present trade barriers and domestic farm policies generate little benefit at enormous cost (*12*), and that the payoff on trade liberalization could be significant. Our objective is to estimate the economic gains (or losses) from trade liberalization in the world wheat market, thus providing a basis for trade negotiations. We reach that objective by developing an export-side international trade model. The model is then used to measure the effect of removing PSE's and CSE's on trade patterns for major grain-trading countries, including the United States, the European Community (EC), Canada, and Japan.

Trade Models and Data Requirements

A primary issue for international trade economists is to quantify the effects of policy change on trade patterns. A number of different trade models have been developed and these are well documented by Thompson (*25*). However, the Armington model and a spatial equilibrium model, which was developed by Samuelson (*22*) and formulated by Takayama and Judge (*24*) as a quadratic programming model, have been most widely used in international trade to quantify the effects of policy change (*2*, *3*, *4*, *5*, *6*, *10*, *11*, *16*, *18*, *19*, *20*). The spatial equilibrium model assumes that the demand functions are integrable so that the Jacobian of the demand functions are symmetric. Under this assumption, the spatial equilibrium model maximizes economic efficiency by reducing transportation costs of a homogeneous commodity. Meanwhile, the Armington model assumes that the importer has a separable utility function, which is maximized through a two-stage optimization. In the first stage, a country's budget is allocated across several sets of commodities in a way that will maximize the importer's utility function. In the second stage, the utility associated with a subset is maximized subject to the budget allocated for commodities of this subset. The Armington model differentiates commodities by country of origin, and therefore, commodities from different exporting countries are imperfect substitutes within an importing country's commodity market. To reduce the number of parameters to be estimated, the Armington model assumes a constant substitution

Kim and Lin are agricultural economists with the Resources and Technology Division and Commodity Economics Division, respectively, ERS. The authors thank Patrick M. O'Brien, Philip L. Paarlberg, and Eduardo Segarra for their helpful comments on an earlier draft.

[1]Italicized numbers in parentheses cite sources listed in the References section at the end of this article.

elasticity for each product pair in an importing country's commodity market.

Even though both the Armington model and the spatial equilibrium model are theoretically sound, the lack of relevant price and transfer cost data discourages researchers from applying these models. Researchers who have attempted to use these models in empirical studies recognize the difficulties associated with data collection, especially the availability of price data from all importing countries, and transfer costs connecting all exporting and importing countries. These can be more clearly explained by considering the following Armington-type model:

$$M_{ij} = b_{ij}^{zj} * M_j * (p^{ij}/PI_j)^{-zj}$$
$$= f_{ij} * (P^{ij})^{-zj} \quad (i = 1, 2, \ldots m;\ j = 1, 2, \ldots, n), \quad (1)$$

where $f_{ij} = M_j * (b_{ij} * PI_j)^{zj}$, b_{ij} is constant, $-zj$ is the constant elasticity of substitution in the jth importing country between varieties of wheat, PIj is the price index of a subset containing wheat in the jth importing country, M_{ij} is the import by the jth importing country from the ith exporting country, p^{ij} is the consumer price of M_{ij}, and M_j is the total wheat import by the jth importing country.

In applying the Armington model, M_{ij} is frequently defined as an import from a region such as South America, the Middle East, Africa, or South Asia in order to reduce the size of a trade matrix. Researchers recognize that reliable estimates of commodity prices and transfer costs are not available for all regions in any base year. Therefore, most researchers use synthetic price and transportation cost data in the application of the Armington model and spatial equilibrium models. Because of the nature of synthetic data, the resulting outcome may be viewed as polyester economics and therefore refutable.

While we do not have reliable price information from most importing countries, we do have reliable information on quantities traded among all importing and exporting countries. Therefore, this article develops the export-side international trade (ESIT) model, which connects spatially separated import and export markets through a quantity mechanism. A similar concept was used in the work of Johnson and others (*15*). The ESIT model requires price information from all exporting countries and from only those importing countries that remove their trade barriers and domestic farm policies. We will reveal that even though 18 importing countries/regions and 5 exporting countries are included in the analysis, price information is needed for only the 5 exporting countries and 1 importing country. Other world trade models would require price information from all 23 countries/regions.

An Export-Side International Trade Model

The ESIT model is based on a two-step procedure. The first step links domestic commodity markets with an international commodity market. The first step illustrates that the horizontal shift in the importing country's domestic commodity demand, or supply curve, to the right or to the left shifts the excess demand curve in the international commodity market to the right or to the left by the same amount. Similarly, the horizontal shift in the exporting country's domestic supply curve or demand curve to the right or to the left shifts the excess supply curve in the international commodity market to the right or to the left by the same amount.

The second step of the ESIT model links the international commodity market with export markets. The export demand of an exporting country is derived by subtracting all other exporting countries' excess supply from the aggregate excess demand in the international market. A market-clearing equilibrium is attained where the excess supply curve intersects the export demand curve for each exporting country.

When an importing country removes its implicit tax on consumers so that its excess demand curve shifts to the right, the export demand curves of all exporting countries simultaneously shift to the right, while their excess supply curves remain unchanged. For each exporting country, new equilibrium export price and quantity are attained where a new export demand curve intersects the unchanged excess supply curve for each exporting country.

When an exporting country removes its subsidy to producers, its excess supply curve shifts to the left along the unchanged export demand curve. For all other exporting countries, however, the export demand curve shifts to the right along the unchanged excess supply curve. For an exporting country that removes its trade barriers, new equilibrium export price and quantity are attained where a new excess supply curve intersects the unchanged export demand curve. For all other exporting countries, a new equilibrium is reached where a new export demand curve intersects the unchanged excess supply curve.

A distinctive characteristic of the ESIT model compared with other existing international trade models, such as the Armington model and the spatial equilibrium model formulated by Takayama and Judge, is that the market-clearing equilibrium is attained through a quantity mechanism at the point where the excess supply curve intersects the export demand curve in each export market. In the Armington model and the spatial equilibrium model, the market-clearing equilibrium is reached, through a price mechanism, at the point where excess demand equals excess supply. So, the ESIT model substantially reduces data requirements from importing countries, such as transfer costs and import or consumer prices.

The functional form of the demand and supply equations does not affect the magnitude of the horizontal

shifts of these demand and supply curves. Therefore, let $D = \alpha - \beta P$ give the domestic demand. When a government removes an implicit consumer tax (negative CSE), the magnitude of horizontal shift is estimated by $-\beta$*CSE. Let the domestic supply curve be given by $S = \gamma + \delta P$. When a government removes its subsidy to producers, the magnitude of horizontal supply shift is estimated by $-\delta$*PSE.

The next step is to estimate the horizontal distance of export demand shifts when an importing country or an exporting country removes the PSE and the CSE. This can be accomplished by considering the following equations of export demand elasticity (*8*, *14*, *26*):

$$E_k = \sum_i^m \sum_j^n Ed_j(P^{ij})*T^j*M_{ij}/X_k(P_k)$$

$$- \sum_{i \neq k,j}^m \sum^n Es_i(p_i)*T_i*X_{ij}/X_k(P_k), \qquad (2)$$

where $k = 1, 2, \ldots\ldots, m$, where E_k is the export demand elasticity of the kth exporting country, Ed is excess demand elasticity, Es is excess supply elasticity, T is the price transmission elasticity, p^{ij} is the domestic price of the import from the ith exporting country in the jth importing country, P_i is the producer price of the ith exporting country, X_{ij} is the export by the ith exporting country to the jth importing country and equals zero if $X_{kj} = 0$, where $i \neq k$, and M_{ij} is the import by the jth importing country from the ith exporting country and equals zero if $X_{kj} = 0$, where $i \neq k$.

In estimating the kth country's export demand elasticity with equation 2, we found that the excess supply of other exporting countries includes only that portion of their exports to countries to which the kth country exports. Equation 2 includes the excess demand of importing countries to which the kth country exports. For instance, Canada did not export to Korea in 1985, and therefore, all exports by other countries to Korea and Korea's imports must be excluded when estimating the export demand elasticity for Canada. The export demand elasticity estimated with equation 2, consequently, is always less than or equal to export demand elasticity estimated with equations used by Bredahl and others (*8*), Johnson (*14*), and Tweeten (*26*).

By multiplying both sides of equation 2 by X_k/E_k, and using minor manipulations, we can rewrite equation 2 as:

$$F_k = \sum_j^n X_k^j (a_k, p_k)$$

$$- \sum_i^m \sum_j^n M_{ij} (f_{ij}, P^{ij})*(Ed_j(P^j)*T^j/E_k)$$

$$+ \sum_{i \neq k,j}^m \sum^n X_{ij} (c_{ij}, P_i)*(Es_i(P_i)*T_i/E_k), \qquad (3)$$

where $k = 1, 2, \ldots, m$, where a, f, and c are intercept terms of the export demand, excess demand, and excess supply functions, respectively. In equation 3, $M_{ij} = X_{ij}$ for all i and j.

Since wheat is a differentiated product, it is assumed that the excess demand of the jth importing country from the ith exporting country is given by the Armington-type import demand in equation 1. Assuming that only h importing countries remove their trade barriers and domestic farm policies and the remaining (n-h) importing countries do not change domestic farm and trade policies, then the implicit function 3 can be rewritten as equation 4 by inserting equation 1 into equation 3:

$$F_k = \sum_j^n X_k^j (a_k^j, P_k)$$

$$+ \sum_{i \neq kj}^m \sum^n (Es_i(P_i)*T_i/E_k)*X_{ij}(C_{ij}, P_i)$$

$$- \sum_j^h \sum_i^m (Ed_j (P^j)*T^j/E_k)*f_{ij}(P^{ij})^{-zj}$$

$$- \sum_g^{n-h} \sum_i^m (Ed_g (P^g)*T^g/E_k)*M_{ig}$$

$$= 0 \qquad \text{for } k = 1, 2, \ldots, m. \qquad (4)$$

Since the excess demand has an Armington-type import demand function in equation 1, the implicit function 4 can be considered as the export-side Armington model. The horizontal distance of the export demand shifts resulting from the horizontal shift of the excess demand and excess supply curves can be estimated by applying the implicit function theorem to the system of m-equations (*4*). Note that there are mn endogenous variables of a_k^j ($k = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n$) and $m(n + h)$ exogenous variables, including c_{ij} ($i \neq k$) and f_{ij} for all i and j.

By applying the implicit function theorem to equation 4, we determined that the horizontal distances of the export demand shifts resulting from removing the PSE and the CSE in the jth importing country are represented by the following equation:

$$\begin{bmatrix} \Delta a_1^j \\ \Delta a_2^j \\ \cdot \\ \cdot \\ \cdot \\ \Delta a_m^j \end{bmatrix} = \begin{bmatrix} \partial X_1^j/\partial f_{ij} & 0 & & \ldots 0 \\ 0 & \partial X_2/\partial f_{ij} & 0 & \ldots 0 \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \\ \cdot & & & \cdot \quad \cdot \\ 0 & 0 & 0 & \cdot \quad \partial X_m/\partial f_{ij} \end{bmatrix}$$

$$
* \begin{bmatrix} (Ed_j*T^j/E_1)*\sum_i^m \Delta f_{ij}*(P^{ij})^{-zj} \\ (Ed_j*T^j/E_2)*\sum_i^m \Delta f_{ij}*(P^{ij})^{-zj} \\ . \\ . \\ (Ed_j*T^j/E_m)*\sum_i^m \Delta f_{ij}*(P^{ij})^{-zj} \end{bmatrix} \quad (5)
$$

The system of equation 5 can be compactly rewritten as:

$$
\begin{aligned}
\Delta a_k^j &= (\partial a_k^j/\partial F_k)*(Ed_j(P^j)*T^j/E_k)*\sum_i^m \Delta f_{ij}*(P^{ij})^{-zj} \\
&= (\partial a_k^j/\partial F_k)*(Ed_j(P^j)*T^j/E_k)*(-\beta^j*CSE^j \\
&\quad + \delta^j*PSE^j), \qquad (6)
\end{aligned}
$$

where k = 1, 2, ... , m; j = 1, 2, ..., h, and where β and δ are the slope coefficients associated with the domestic commodity demand and supply functions, respectively.

The price transmission elasticity T^j in equation 6 equals one when the importing country removes its trade barriers. Note that the horizontal distance of the excess demand shift in equation 6 is replaced with the horizontal distance of the domestic commodity demand or supply shift. The market-clearing condition is given by the following equation:

$$
\sum_j^n X_k^j(a_k^j + \Delta a_k^j, P_k^*) = \sum_j^n X_{kj}(c_{kj}, P_k^*), \qquad (7)
$$

where k = 1, 2, ... , m, and where the left-hand side and the right-hand side of the equality in equation 7 represent the export demand and excess supply, respectively, of the kth exporting country after trade liberalization. The export price of the kth exporting country, P_k^*, is obtained from solving equation 7 for P_k. Exports by the kth country to the jth importing country are obtained by inserting P_k^* into equation 7.

The horizontal distances of the export demand shifts resulting from removing the PSE and the CSE in the ith exporting country, Δa_k^i, are given by the following equation:

$$
\begin{aligned}
\Delta a_k^i &= -(\partial a_k^j/\partial F_k)*(Es_i(P_i)*T_i/E_k)*(\delta_i*PSE_i \\
&\quad - \beta_i*CSE_i), \qquad (8)
\end{aligned}
$$

where k = 1, 2, ... , m and $k \neq i$, where δ_i and β_i are the slope coefficients associated with the ith exporting country's domestic supply and demand functions, respectively. The price transmission elasticity T_i in equation 8 also equals one when the ith exporting country removes both the PSE and CSE.

Market-clearing conditions are given by the following equations:

$$
\sum_j^n X_k^j(a_k + \Delta a_k^i, P_k^*) = \sum_j^n X_{kj}(c_{kj}, P_k^*), \qquad (9a)
$$

where k = 1, 2, ... , m and $k \neq i$. and

$$
\sum_j^n X_i^j(a_i, P_i^*) = \sum_j^n X_{ij}(c_{ij} + \Delta c_{ij}, P_i^*) \qquad (9b)
$$

where i = k.

Export prices are then estimated from equations 9a and 9b. Exports by the kth country to the jth importing country are obtained by substituting estimated P_k^* and P_i^* into equations 9a and 9b, respectively.

Trade Pattern Effects of Industrialized Countries' Trade Liberalization in the World Wheat Market

Since the functional form of domestic demand and supply functions, the export demand function, and the excess supply function do not affect the magnitude of the horizontal shifts of these curves, we assumed that domestic demand and supply functions, the export demand function, and the excess supply functions are linear. Domestic supply and demand equations are estimated for the United States, EC, Canada, Argentina, Australia, and Japan (tables 1-3). The domestic supply equations follow: United States: Q = 56,494.4 + 93.53P; EC: Q = 53,271.4 + 147.29P; Canada: Q = 17,595.17 + 20.59P; Argentina: Q = 11,968.0 + 13.06P; Australia: Q = 16,799.4 + 12.44P; and Japan: Q = 666.9 + 0.0756P. Domestic demand equations are estimated as follows: United States: Q = 37,306.0 – 32.2252P; EC: Q = 70,590.0 – 68.4012P; Canada: Q = 1,779.8 – 0.9246P; Argentina: Q = 5,954.55 – 2.2684P; Australia: Q = 3,779.6 – 2.2907P; and Japan: Q = 7,786.8 – 3.6765P.

The per-unit PSE's and CSE's measure the magnitude of the vertical shifts of the domestic supply and demand curves (table 2). To use the ESIT model, the PSE's and CSE's must be converted into horizontal distances of domestic supply and demand shifts. These conversions can be made with the slopes of the estimated domestic demand and supply equations.

We used the Delphi method to estimate the constant elasticity of substitution (excess demand elasticity) for the jth country (table 3). Use of the Delphi method is well justified by Abbott (*1*) and McCalla and others (*18*), and more justifiable than using the same constant elasticity of substitution across all importing countries/regions. The excess supply elasticity of the ith exporting country is also estimated with the Delphi method.

The estimated excess supply equations follow: Argentina: 6,013.45 + 15.3244P; Australia: 12,643.8 +

14.7347P; Canada: 14,936.37 + 21.5179P; EC: –18,758.1 + 223.2330P; and United States: 13,424.4 + 125.7589P. The excess supply elasticity is perceived by all importing countries to be constant. By using trade flows, we can estimate the excess supply equation for the kth country to the jth importing country for all k and j. Price transmission elasticities (table 1) range between 0 and 1. However, the price transmission elasticity will equal 1 when all trade barriers are removed. Export demand elasticities estimated with equation 2 are United States: –1.275; Canada: –2.932; EC: –3.206; Australia: –3.122; and Argentina: –6.298. The estimated export demand equations: Argentina: EX = 57,868.2 – 399.51P; Australia; EX = 61,222.24 – 309.12P; Canada: EX = 73,541.87 – 313.37P; EC: EX = 66,635.658 – 327.69P; and U.S.: EX = 73,741.85 – 273.69P. Table 4 presents estimated trade flows and export prices under the conditions that the United States, EC, Canada, and Japan remove all PSE's and CSE's. Results indicate that the volume of world wheat trade is expected to decline to 84.9 million metric tons (MT) from 89.7 million MT if major trading countries remove all PSE's and CSE's. Canada's exports would decline slightly from 18.7 million MT to 17.9 million MT, while it's export price would rise from \$175/MT to \$178.76/MT. U.S. exports would

Table 1—Wheat base-year data for simulation, 1984/85

Country/region	Production	Consumption	Net trade	e[3]	n[3]	T[4]
		1,000 metric tons				
Argentina	13,600	5,671	7,929	0.12	−0.05	0.50
Australia	18,666	3,436	14,854	.10	−.10	.90
Canada	21,199	1,618	18,702	.17	−.10	1.00
European Community[1]	76,102	58,825	15,843	.30	−.20	.10
United States	70,618	32,440	32,414	.20	−.15	1.00
European Community[2]	0	2,206	−2,206	0	−.20	.10
Western Europe	16,627	16,240	−1,126	.30	−.20	.25
Eastern Europe	36,460	36,563	−1.856	.20	−.10	.40
USSR	68,600	94,531	−25,931	.20	−.15	.32
North/Central America	4,506	7,172	−2,666	.15	−.17	.52
Brazil	1,956	6,883	−4,927	.15	−.12	.20
South America	1,601	5,485	−3,884	.15	−.12	1.00
Japan	741	6,489	−5,748	.10	−.20	.10
Korea	17	3,060	−3,043	.10	−.20	.60
China	87,820	94,994	−7,174	.10	−.25	.20
Indonesia	0	1,187	−1,187	0	−.20	.40
Middle East	26,950	37,069	−10,119	.04	−.12	.40
South Asia	50,402	53,725	−3,323	.10	−.20	.20
East Asia	0	1,003	−1,003	0	−.15	.60
Nigeria	45	1,845	−1,800	.20	−.20	.14
North Africa	3,494	9,090	−5,596	.04	−.12	.40
Egypt	1,875	6,732	−4,857	.12	−.17	.25
Other Africa	0	3,296	−3,296	0	−.25	.40

[1]EC exporter.
[2]EC importer.
[3]Source: (*21*).
[4]Source: (*28*).

Table 2—Wheat average PSE's and CSE's during 1982-86

Country	Consumer price	Producer price	PSE/ metric ton	CSE/ metric ton	Horizontal distance PSE	Horizontal distance CSE
		---*U.S. dollars per metric ton*---			---*1,000 metric tons*---	
Canada	175	175	41	0	−848	0
European Community[1]	172	155	48	−37	−7,093	2,572
Japan	353	980	795	−116	−60	430
United States[2]	151	151	57	−0	1,562	0

[1]The subsidy equivalents represent a weighted average for durum wheat and soft wheat.
[2]Acreage allocated for wheat production and for acreage reduction and conservation programs are 79.2 million acres and 18.3 million acres in 1984, respectively. Production forgone from set-aside acreage was based on 50 percent of acreage slippage and yields, which were 85 percent of yields for planted cropland. When the United States removes producers' subsidies, the domestic supply curve initially shifts to the left by 5.3 million metric tons, but it shifts back to the right by 6.9 million metric tons due to a relaxed acreage reduction program.

Source: (*27*).

Table 3—Wheat base-year data for trade, 1984/85

Importing country/ regions	Exporting country/region						
	Argentina	Australia	Canada	European Community	United States	Subtotal	Ed_j[1]
	1,000 metric tons						
European Community	54	0	1,273	0	879	2,206	−0.20
Western Europe	31	0	96	345	654	1,126	−7.05
Eastern Europe	57	368	235	1,131	65	1,856	−5.80
USSR	4,057	2,040	7,633	6,078	6,123	25,931	−1.08
North/Central America	262	425	878	387	714	2,666	−.71
Brazil	660	0	1,185	51	3,031	4,927	−.23
South America	698	0	398	32	2,756	3,884	−.23
Japan	0	1,039	1,385	0	3,324	5,748	−.24
Korea	0	973	0	0	2,070	3,043	−.20
China	675	1,348	2,634	62	2,455	7,174	−4.53
Indonesia	74	502	200	0	411	1,187	−.20
Middle East	1,163	4,149	833	1,441	2,533	10,119	−.55
South Asia	91	1,282	129	359	1,462	3,323	−4.75
East Asia	12	105	124	0	762	1,003	−.15
Nigeria	95	0	21	18	1,666	1,800	−.21
North Africa	0	0	575	2,558	2,463	5,596	−.22
Egypt	0	2,168	443	1,450	796	4,857	−.28
Other Africa	0	455	660	1,931	250	3,296	−.25
Subtotal	7,929	14,854	18,702	15,843	32,414	89,742	
Es_i[2]	.242	.149	.201	2.184	.586		
Price ($/MT)	125	150	175	155	151		

[1] Ed_j is excess demand elasticity.
[2] Es_i is excess supply elasticity.

increase by 1.6 million MT to 34.1 million MT, and its export price would remain about the same. EC exports would suffer the most, declining by nearly 6 million MT, from 15.8 million MT to 10 million MT, while its export price would rise to $172/MT from $155/MT. Japan's excess demand curve would be expected to shift to the right as a result of trade liberalization, so that Japan's wheat imports increase at a higher price. Results show, however, that imports by Japan would increase only slightly, by 112,000 MT, to 5.9 million MT, which may reflect the fact that the increase in imports resulting from the horizontal shift to the right of the excess demand curve is offset by reduced imports from the higher import price.

While reduced exports by the EC and Canada would total 6.6 million MT, Argentina, Australia, and the United States would increase their exports by 1.7 million MT. Therefore, the world wheat trade would decline by nearly 5 million MT to 84.8 million MT. The increase in exports in Argentina and Australia would be only 28,000 MT. Both the inelastic excess supply and the very elastic export demand for Argentina and Australia may be responsible for their sluggish increase in exports.

Gains from Industrialized Countries' Trade Liberalization in the World Wheat Market

Trade liberalization affects not only trade patterns but the social welfare of all countries as well. We used the partial equilibrium approach as a theoretical framework to estimate the effect of trade liberalization in the world wheat market on social welfare. We estimated both consumers' surpluses (CS) and producers' surpluses (PS) with the following equations:

$$\Delta CS = \int_0^{Qc'} (\alpha'/\beta - q/\beta)dq - \int_0^{Qc} (\alpha/\beta - q/\beta)dq - (P'Qc' - PcQc); \qquad (10)$$

$$\Delta PS = \int_0^{Qs'} (-\gamma'/\delta + q/\delta)dq - \int_0^{Qs} (-\gamma'/\delta + q/\delta)dq - (P'Qs' - PsQs), \qquad (11)$$

where α and α' are intercept terms for the domestic demand curve before and after trade liberalization, respectively, β is the slope coefficient of the domestic demand curve, γ and γ' are intercept terms for the domestic supply curve before and after trade liberalization, respectively, δ is the slope coefficient of the domestic supply curve, Qc and Qc' are domestic consumer demand before and after trade liberalization, Qs and Qs' are domestic supply before and after trade liberalization, respectively, Pc and Ps are consumer and producer prices before trade liberalization, and P' is domestic market price after trade liberalization. Estimated domestic supply curves often intersect the horizontal axis. For these cases, we employed the formula used by Kim and others (*17*) for estimating the changes of producers' surpluses. Changes in con-

sumers' and producers' surpluses are estimated for the United States, EC, Canada, Argentina, Australia, and Japan. Estimated changes in U.S. consumers' and producers' benefits resulting from trade liberalization in the world wheat market are –$19.3 million and $278.9 million, respectively (table 5). Even though the domestic supply curve shifts to the right by 1.6 million MT, the U.S. export demand curve also shifts to the right by 1.8 million MT, resulting in an insignificant increase. Domestic consumption would decline slightly from 32.44 million MT to 32.42 million MT, while domestic supply would likely rise from 70.6 million MT to 72.2 million MT.

Changes in Canada's consumer and producer benefits resulting from trade liberalization in the world wheat market would be –$6.1 million and –$779.2 million, respectively. Domestic production probably would decline from 21.2 million MT to 20.4 million MT, while price would rise from $175 per MT to $179 per MT. Meanwhile, consumer demand would fall slightly, by 3,000 MT (0.01 percent).

EC producers would expect to reduce their benefits substantially as a result of trade liberalization in the world wheat market, while EC consumer benefits would increase enormously. Changes in EC consumer and producer benefits would be $2.3 billion and –$2.3 billion, respectively. Domestic wheat consumption would likely increase by 2.6 million MT to 61.4 million MT, and the consumer price would rise slightly to just over $172 per MT. Domestic supply would decline by 4.6 million MT to 71.5 million MT, but producer prices would rise substantially from $155 per MT to $172 per MT. Gains to consumers resulting from trade liberalization are large enough to offset most losses to producers due to reduced production.

Consumer demands for wheat in both Argentina and Australia would decline slightly as prices rise, while

Table 4—Estimated trade patterns after industrialized countries' trade liberalization in the world wheat market

Importing country/region	Exporting country/region					
	Argentina	Australia	Canada	EC	United States	Subtotal
			1,000 metric tons			
European Community	54	0	1,221	0	923	2,198
Western Europe	31	0	92	218	687	1,028
Eastern Europe	57	368	225	714	68	1,432
USSR	4,061	2,043	7,320	3,837	6,432	23,693
North/Central America	262	426	842	244	750	2,524
Brazil	661	0	1,136	32	3,184	5,013
South America	699	0	382	20	2,895	3,996
Japan	0	1,040	1,328	0	3,492	5,860
Korea	0	974	0	0	2,175	3,149
China	676	1,350	2,526	39	2,579	7,170
Indonesia	74	503	192	0	432	1,201
Middle East	1,164	4,154	799	910	2,661	9,688
South Asia	91	1,284	124	227	1,536	3,262
East Asia	12	105	119	0	801	1,037
Nigeria	95	0	20	11	1,750	1,876
North Africa	0	0	551	1,615	2,587	4,753
Egypt	0	2,171	425	915	836	4,347
Other Africa	0	456	633	1,219	263	2,571
Subtotal	7,937	14,874	17,935	10,001	34,051	84,798
Price ($/MT)	125.53	151.37	178.76	172.13	151.60	

Table 5—Gains (or losses) from industrialized countries' trade liberalization in the world wheat market

Item	Argentina	Australia	United States	Canada	European Community	Japan
			Million dollars			
Changes in consumer surplus	–3.0	–4.7	–19.3	–6.1	2,252.9	72.4
Changes in producer surplus	7.2	25.5	278.9	–779.2	–2,290.0	–420.3
Net changes in surplus	4.2	20.8	259.6	–785.3	–37.1	–347.9
Savings in Government expenditure equivalent	1.12[1]	0	4,027.3	873.4	1,452.7	–169.5
Gains (or losses) to taxpayer	5.32	20.8	4,286.9	88.1	1,415.6	–544.1
Effectiveness ratio[2]	–3.75	0	–.06	.90	.03	–2.05

[1] Export tax rate for 1985 was 21.5 percent.
[2] Effectiveness ratio = Minus net changes in surplus/savings in government expenditure equivalent.

producers in both countries would slightly increase their production. Consumer demand in Argentina would decline slightly (1,000 MT; 0.02 percent), while producers would increase their wheat production by 7,000 MT (0.05 percent) to 13.61 million MT. Consumers in Australia would reduce their wheat consumption by 3,000 MT (0.09 percent) and producer output would climb by 17,000 MT (0.09 percent). Wheat production in Japan would decline by 135,000 MT (18 percent). Consumer demand, however, would rise by 41,000 MT (6 percent), resulting in an increase in imports of 112,000 MT (1.9 percent).

We estimate net changes resulting from trade liberalization in the world wheat market at $4.3 billion for the United States, $88 million for Canada, $1.4 billion for the EC, $5.3 million for Argentina, $20.8 million for Australia, and −$517 million for Japan. The magnitude of the net changes not only would be influenced by trade barriers and domestic farm policy but would depend on the magnitude of production levels. Therefore, we estimated an effectiveness ratio of government intervention which is the ratio of welfare gains resulting from government subsidies compared with government expenditures that subsidize both consumers and producers. The estimated effectiveness ratio is −0.06 for the United States, 0.90 for Canada, 0.03 for the EC, and −2.05 for Japan. For example, when the United States spends 1 dollar to subsidize wheat producers, social welfare resulting from government subsidies would decline by 6 cents. When the EC spends 1 dollar to subsidize producers or tax consumers, social welfare increases by 3 cents. EC trade barriers and farm policy somewhat punish consumers while protecting producers in the EC. As a result of trade liberalization in the world wheat market, EC consumer benefits would increase substantially by $2.3 billion, while producer benefits would decline by slightly more. The EC spent $1.5 billion for subsidies, which generated just $37 million of social welfare enhancement.

Canadian trade barriers and farm policy reallocated social benefits from taxpayers to producers. When the Canadian Government spent 1 dollar to subsidize producers, their benefits increased by 90 cents.

We did not estimate gains from trade liberalization for other importing countries because of limited information about domestic or import prices. However, it is possible to provide a qualitative analysis of effects on trade patterns and gains from trade liberalization for these countries. When all PSE's and CSE's in importing countries are removed, domestic demand increases and supply declines. However, when all PSE's and CSE's are removed from all exporting countries so that export prices rise, domestic production increases and domestic demand declines. Consequently, changes in social welfare in importing countries depend mainly on the relative size of PSE's, CSE's, and changes in export prices.

Limitations and Conclusions

These results indicate that government subsidies to wheat producers and consumers do not generate an adequate level of social welfare. Because members of GATT are currently negotiating for trade liberalization, this study offers the timely advice that trade barriers are unlikely to be beneficial to all exporting countries.

Price elasticities of domestic demand and supply affect the magnitude of welfare effects of trade liberalization. Domestic demand and supply equations, however, are synthesized by using secondary data in a crude manner. Further econometric study is necessary for confirmation of elasticities used in this article. Also, the foregoing analysis ignored the longrun effect on domestic supply of trade liberalization in the world wheat and corn markets. Producers are expected to react to changing prices and to increased uncertainty associated with market prices.

References

1. Abbott, P.C. "Estimating U.S. Agricultural Export Demand Elasticities: Econometric and Economic Issues," *Elasticities in International Agricultural Trade*. C. Carter and W. Gardner (eds.). Boulder, CO: Westview Press, Inc., 1988.

2. Abbott, P.C., and P.L. Paarlberg. "Modeling the Impact of the 1980 Grain Embargo," *Embargoes, Surplus Disposal, and U.S. Agriculture*. Staff Report No. AGES860910. U.S. Dept. Agr., Econ. Res. Serv., Nov. 1986.

3. Adelman, I., and S. Robinson. "Macroeconomic Shocks, Foreign Trade, and Structural Adjustment: A General Equilibrium Analysis of the U.S. Economy, 1982-86," *Elasticities in International Agricultural Trade*. C. Carter and W. Gardner (eds.). Boulder, CO: Westview Press, 1989.

4. Armington, Paul S. "A Theory of Demand for Products Distinguished by Place of Production." IMF staff papers. Vol. 16, No. 1, 1969, pp. 159-78.

5. __________. "Geographic Pattern of Trade and Effects of Price Changes." IMF staff papers. Vol. 16, No. 1, 1969, pp. 179-201.

6. Babula, R.A. "An Armington Model of U.S. Cotton Exports," *The Journal of Agricultural Economics Research*. Vol. 39, No. 4, 1987.

7. Ballenger, Nicole. "PSEs: What They Are And Their Role In Trade Negotiations," *Choices*. First quarter, 1988, pp. 36-37.

8. Bredahl, M.E., W.H. Meyers, and K.J. Collins. "The Elasticity of Foreign Demand for U.S. Agricultural Products: The Importance of the Price Transmission Elasticity," *American Journal of Agricultural Economics*. Vol. 61, No. 1, 1979, pp. 58-63.

9. FAO Production Year Book, 1985.

10. Figueroa, E.E., and A. Webb. "An Analysis of the U.S. Grain Embargo Using a Quarterly Armington-Type Model," *Embargoes, Surplus Disposal, and U.S. Agriculture*. Staff Report No. AGES860910. U.S. Dept. Agr., Econ. Res. Serv., Nov. 1986.

11. Grennes, T.J., P.R. Johnson, and Marie Thursby. *The Economics of World Grain Trades*. New York: Praeger Publishers, 1978.

12. Hillman, Jimmye S. "Nontariff Barriers: Major Problems in Agricultural Trade," *American Journal of Agricultural Economics*. Vol. 60, No. 3, 1978, pp. 491-501.

13. Jabara, Cathy L. *Trade Restrictions in International Grains and Oilseed Markets*. FAER-162. U.S. Dept. Agr., Econ. Res. Serv., 1981.

14. Johnson, P.R. "The Elasticity of Foreign Demand for U.S. Agricultural Products," *American Journal of Agricultural Economics*. Vol. 59, No. 4, 1977, pp. 735-36.

15. Johnson, P.R., T. Grennes, and M. Thursby. "Devaluation, Foreign Trade Controls, and Domestic Wheat Price," *American Journal of Agricultural Economics*. Vol. 59, 1977, pp. 619-27.

16. __________. "Trade Models with Differentiated Products," *American Journal of Agricultural Economics*. Vol. 61, 1979, pp. 120-7.

17. Kim, C.S., G. Schaible, J. Hamilton, and K. Barney. "Economic Impacts on Growers, Processors, and Consumers Resulting from Mechanical Tomato Harvesting in California: Revisited," *The Journal of Agricultural Economics Research*. Vol. 39, No. 2, 1987.

18. McCalla, A., P. Abbott, and P. Paarlberg. "Policy Interdependence, Country Response, and Analytical Challenge," *Embargoes, Surplus Disposal, and U.S. Agriculture*. Staff Report No. AGES860910. U.S. Dept. Agr., Econ. Res. Serv., 1986.

19. McDonald, Bradley J. "World Agricultural Policy Liberation." Presented at the annual American Agricultural Economics Association meeting, Baton Rouge, LA, Jul. 30-Aug. 2, 1989.

20. Shei, S.Y., and R.L. Thompson. "The Impact of Trade Restrictions on Price Stability in the World Wheat Market," *American Journal of Agricultural Economics*. Vol. 59, 1977, pp. 628-38.

21. Sarris, Alexander H., and John Freebairn. "Endogenous Price Policies and International Wheat Prices," *American Journal of Agricultural Economics*. Vol. 65, 1983, pp. 214-24.

22. Samuelson, Paul. "Spatial Price Equilibrium and Linear Programming," *American Economic Review*. Vol. 42, No. 2, 1952, pp. 283-303.

23. Schmitz, Andrew, Dale Sigurdson, and Otto Doering. "Domestic Farm Policy and the Gains from Trade," *American Journal of Agricultural Economics*. Vol. 68, No. 4, 1986, pp. 820-27.

24. Takayama, T., and G.G. Judge. "Spatial Equilibrium and Quadratic Programming," *American Journal of Agricultural Economics*. Vol. 46, No. 1, pp. 67-93, 1964.

25. Thompson, B.L. *A Survey of Recent U.S. Developments in International Trade Models*. BLA-21. U.S. Dept. Agr., Econ. Res. Serv., Sept. 1981.

26. Tweeten, Luther. "The Elasticity of Foreign Demand for U.S. Agricultural Products: Comment," *American Journal of Agricultural Economics*. Vol. 59, No. 4, 1977, pp. 737-38.

27. U.S. Department of Agriculture, Economic Research Service. *Estimates of Producer and Consumer Subsidy Equivalents: Government Intervention in Agriculture, 1982-86*. ERS Staff Report No. AGES880127. U.S. Dept. Agr., Econ. Res. Serv., 1988.

28. U.S. Department of Agriculture, Economic Research Service. *Embargoes, Surplus Disposal, and U.S. Agriculture*. Staff Report No. AGES860910. 1986.

29. World Wheat Statistics, 1987.

Partial Adoption of Divisible Technologies in Agriculture

Philip I. Szmedra, Michael E. Wetzstein, and Ronald W. McClendon

Abstract. *We have developed a dynamic theoretical model to investigate technology complements where the degree of adoption is a function of producers' prior technology levels. Based on this model, we used an empirical application to assess the adoption of integrated pest management (IPM) with and without irrigation. Results indicate that the degree of new technology adoption may depend on the extent of the risk. For example, strongly risk-averse producers who use dryland technology may only partially adopt IPM. And producers who irrigate to significantly decrease variation in yield and returns may also only partially adopt IPM.*

Keywords. *Pest management, irrigation, simulation, soybeans, technology adoption.*

Conventional theories describing technology adoption in agriculture have addressed constraints to adoption associated with profitability, riskiness, and divisibility. These constraints generally deal with farm tenure arrangements, aversion to risk, imperfect information markets, inadequate farm size, and lack of credit (*8*).[1] Availability of technologies has been investigated for inappropriate infrastructure, chaotic supply of complementary inputs, and absence of equipment to relieve labor shortages (*3*). Removing these constraints, however, has generally not resulted in immediate adoption which focuses attention on complexity and how it influences new technology adoption.

Theoretical research and empirical research attempt to isolate the characteristics of separate technologies as the key determinants of the adoption decision (*5*). Byerlee and de Polanco provide evidence that farmers adopt in a sequential manner, in some instances adopting a complete package of new technologies, but more likely practice partial adoption by accepting only a portion of a technology (*3*). Farmer decisions regarding new technology adoption probably depend on the number and complexity of existing production technologies and the way in which a new technique would complement the existing technology mix. Our article considers this notion.

The article investigates farmer decisions regarding technology adoption when an existing set of prior technologies is considered. A theoretical model designed to investigate technology complements is developed in a stochastic setting, where the degree of adoption is a function of producers' prior technology levels. An application reveals varying levels of integrated pest management (IPM) adoption for soybean farmers with and without prior irrigation technology.

Analytical Framework

Development of a theoretical model that incorporates various levels of a prior technology, partial or total adoption of new technologies, producers' production and profit functions, and the stochastic nature of returns may give insight into the technology adoption process. Building on the groundwork of Antle, and Caswell and Zilberman, we let $q_{t+1} = f\,[q_t(e_t)]$ represent a production transformation from time t to t+1 in an annual production process ($t = 1, \ldots T$). Where q_t denotes the state of the output in time t, e_t is a decision variable and denotes the degree of adoption of a new technology package, $q_t(e_t)$, is a function representing the effect of e_t on q_t, and f(.) is a function representing the change in the state of output from time t to t+1 given q_t and e_t. The state of output may define the conditions of the soybean crop, including vegetative growth, blooms, and fruit set. Defining a_t as the amount of the new technology available or purchased, variable e_t represents partial adoption of this new technology. In terms of pest information, e_t denotes the subset of the information technology package purchased by the farmer in time period t which is actually incorporated into the production process.

Based on farmers' level of technical expertise, the type of production technologies currently being used, and the complexity arising from attempting to successfully integrate current methods, farmers may incorporate only a portion of a new technology into their production process. The level of farmers' prior technology, α, influences both $e^*_t(\alpha)$ and $a^*_t(\alpha)$, where $e^*_t(\alpha)$ and $a^*_t(\alpha)$ denote the effective level of partial adoption and the optimal amount of the new technology purchased, respectively. The ratio of partial adoption to purchased technology is also determined by a, denoted as $h_t(\alpha)$, and is defined by the identity $h_t(\alpha) \equiv e_t(\alpha)/a_t(\alpha)$. This identity provides a link between the level of partial adoption and the level of a purchased technology.

As noted by Byerlee and de Polanco, interactions among technologies will affect adoption patterns. If a new technology package tends to complement prior technologies, then $h_t' > 0$, $h_t'' < 0$, where $h_t' = dh/d\alpha$ and $h_t'' = d^2h/d\alpha^2$. However, if a substitution relation

Szmedra is an agricultural economist with the Resources and Technology Division, ERS. Wetzstein is a professor, Department of Agricultural Economics, Univ. of Georgia, Athens; and McClendon is an associate professor, Department of Agricultural Engineering, University of Georgia, Athens.

[1]Italicized numbers in parentheses cite sources listed in the References section at the end of the article.

exists, then $h_t' < 0, h_t'' = 0$. The derivative relations indicate the effectiveness with which the new technology is integrated into the production scheme. A complement relationship between prior and new technologies indicates that an increase in prior technology will increase degree of adoption of the new technology at an increasing rate, whereas a substitute relationship indicates that an increase in prior technology will increase degree of adoption of the new technology at a decreasing rate.

Expected net return in the initial time period, $E(\pi_1)$, resulting from the adoption of a new technology, can be specified as:

$$E[\pi_1(q_1, e_1, \ldots, e_T)] = \sum_{t=1}^{T} E[I_t(q_t, e_t)],$$

where E is the expectations operator and $I_t(.)$ denotes the distribution of returns at time period t. The functional form of $I_t(.)$ is:

$$I_t(q_t, e_t) = p_t q_t - w_t a_t,$$

where p_t is output price associated with the marketable portion of q_t, and $w_t a_t$ denotes the cost of the technology package in period t. If all of the output is harvested at terminal time, T, then $I_t \geq 0$ for $t = 1, \ldots, T-1$ and $I_t > 0$ at T. The solution to this problem may be obtained with dynamic programming (*13*). Let $p_t^*(q_t)$ denote the optimal performance function which is the optimal value of q_t for problems starting at state q_t at time t. By the optimality principle,

$$\pi_t^*(q_t) = \max_{a_t} \{E(I_t) + \pi p^*_{+1}[f(q_t, e_t)]\}.$$

The first-order condition for maximization of $\pi_t^*(q_t)$ is:

$$\partial \pi_t^*(q_t)/\partial a_t = \partial E(I_t)/\partial a_t + \partial p^*_{+1}/\partial a_t = 0. \quad (1)$$

Risk preference may be incorporated into the objective function by replacing expected returns in time t with farmer preference ordering, $U(I_t)$, assuming the eight postulates outlined by Just and Pope (*12*). Given an analytic function, a Taylor series expansion about the expected value of I_t, $E(I_t)$, is:

$$U(I_t) = \sum_{k=0}^{\infty} \{E[I_t - E(I_t)]^k/k!\} U^{(k)},$$

where $U^{(k)}$ denotes the k^{th} derivative of U. Thus, the utility function of a risky prospect I_t is assumed to be equal to the utility function evaluated at the first moment of I_t plus the products of the higher moments of I_t, the corresponding derivative of the utility function, and the inverse factorial. Letting M_k denote the k^{th} moment of I_t, the first-order maximization of $U = U(M_o, M_1, M_2, \ldots, M_\infty)$ yields:

$$\partial U(I_t)/\partial_{at} = \sum_{k=0}^{\infty} (\partial U/\partial M_k)(\partial M_k/\partial a_t) = 0.$$

Note that:

$$\partial M_0/\partial a_t = \partial E(I_t)/\partial a_t = p_t q_t' h_t - w_t,$$

given $q_t(e_t)$, $e_t = h_t a_t$, and $q_t' = \partial q_t/\partial e_t$.

Thus, this follows:

$$\partial U(I_t)/\partial a_t = [\partial U/\partial E(I_t)](p_t q_t' h_t - w_t)$$

$$+ \sum_{k=1}^{\infty} (\partial U/\partial M_k)(\partial M_k/\partial a_t) = 0. \quad (2)$$

Incorporating risk preference into equation 1 given equation 2 yields:

$$\partial \pi_t^*(q_t)/\partial a_t = \partial U(I_t)/\partial a_t + \partial p^*_{+1}/\partial a_t = 0.$$

Rearranging terms yields:

$$w_t = p_t q_t' h_t + \sum_{k=1}^{\infty} \{(\partial U/\partial M_k)/[\partial U/\partial E(I_t)]\}(\partial M_k/\partial a_t)$$

$$+ (\partial p^*_{+1}/\partial a_t)/[\partial U/\partial E(I_t)]. \quad (3)$$

The optimal value of available or purchased technologies, a_t, occurs when the marginal cost of a_t equals the value of expected marginal product times the adoption ratio plus the summation of the rate of utility substitution between E(I) and M_k moments plus the future marginal increment to the objective functional weighted by producer's marginal preferences. Thus, both risk preference and dynamic production influence the optimal level of available technology.

The relative importance of modeling risk preference versus dynamics is open to empirical investigation. However, of interest in this study is the influence of a prior technology and risk aversion on adoption of new technologies. First, consider a producer's optimal adoption level of a technology given a prior technology by isolating prior technology effects from risk aversion. Following Caswell and Zilberman's assumption of a static production relation and without loss of generality, a producer's optimal amount of a new technology package is determined by total differentiation of equation 1 and by analyzing the comparative statics results. This gives:

$$pq''(ha' + ah')h + pq'h' = 0,$$

where $q'' = \partial^2 q/\partial e^2$ and $a' = da/da$.

Rearranging terms yields:

$$a' = -a\phi/\alpha + a\phi/\alpha\epsilon, \quad (4)$$

where $u = h'a/h$ denotes the elasticity of partial technology adoption, and $e = -q''e/q'$ denotes the elasticity of marginal product of partial technology adoption. The total effect of a change in prior technology, a, on purchases of the new technology, a, is a'. This total effect may be decomposed into the substitution and output effects, the first and second terms on the right-hand side of equation 4. If ϵ is zero, the degree of adoption, e, does not influence the marginal product of adoption. Thus, the output effect associated with the influence of a change in α on a is zero, and only the substitution effect remains. If ϵ equals one, however, the output effect just offsets the substitution effect and the total effect, a', is zero. As indicated in equation 4, the level of new technology adoption, e, influences the degree to which prior technology affects new technology purchases. When a new technology package tends to complement a prior technology ($h' > 0$), then:

$$a' \underset{>}{\leq} 0 \text{ if } \epsilon \underset{>}{\leq} 1.$$

A relatively strong decrease in marginal product of partial adoption is associated with $\epsilon > 1$ given an increase in e, while $0 < \epsilon < 1$ corresponds to a relatively small change in marginal product. Thus, for $\epsilon > 1$ the decline in marginal product offsets the increase in h resulting in $a' < 0$. Alternatively, a new technology package, a, that is a substitute for prior technology ($h' < 0$), results in:

$$a' \underset{>}{\leq} 0 \text{ if } \epsilon \underset{>}{\leq} 1.$$

When $\epsilon > 1$ the increase in marginal product offsets the decline in h resulting in $a' > 0$.[2]

A consideration of risk or dynamic properties may either mitigate or augment the response of a to a change in α. Analysis using comparative statics methods when risk and dynamics are incorporated usually results in intractable outcomes. However, assuming risk-averse producer behavior, it may be hypothesized that if a is a risk-reducing (–increasing) technology, the greater the effect of a on the second and subsequent moments of π, given a change in α, the higher (lower) is the adoption rate of a. In a dynamic risk-neutral model, if an increase in a reduces the π moments' magnitudes, a higher adoption rate of a may be hypothesized. Thus, the risk and dynamic processes may work in tandem and are not necessarily mutually exclusive.

An implication of this analysis is that a heterogeneous set of prior technologies cannot be ignored when the adoption of new technologies is being investigated. Feder and others noted that when prior technologies are constantly being modified with the addition of new technologies, equilibrium may never be attained (*8*). This is particularly true when risk preferences and dynamic processes are considered.

Application

Much of the empirical work on technology adoption has lacked a theoretical and biophysical basis on which to specify relations and interdependencies. Endogenous variables are often employed as explanatory variables without regard for the simultaneous equation bias that may result (*8*). Dynamic programming provides an indication of which policies should be investigated further. Finding an optimal policy using dynamic programming, however, becomes intractable as the complexity of a process increases. Simulation modeling is an alternative method. Useful for analysis is a simulation model comprised of a system of differential equations detailing crop growth, including soil, water, insect growth and damage, and economic components that include endogeneous constraints such as producers' risk aversion. A combination of risk and dynamics is a standard justification for use of simulation models (*11*).

The Soybean Integrated Crop Management Model

We used the Soybean Integrated Crop Management Model (SICM) to demonstrate the technology adoption model developed above (*23*). SICM allows a comprehensive development of insect and crop interaction. The SICM model incorporates soil, water, insect, and economic components in detailing crop growth. The primary component of the SICM model is SOYGRO, a soybean growth and yield routine. Physiological processes of photosynthesis, respiration, tissue synthesis, nitrogen remobilization, and senescence in the model depend on weather, as well as soil and crop conditions. These processes are linked mathematically by a series of differential equations that depend on the phenological phase of crop development. The mathematical structure of the soybean crop model describes processes or parameters that depend on growth phase, weather, and the state of the crop to update the evolution of the crop cycle.

The model includes three insect routines which represent the principal sources of diminished yield in soybeans due to insect damage in the Southeastern United States. The insects are the velvetbean caterpillar (VBC), *Anticarsia gemmatalis* (Hubner), the corn earworm (CEW), *Heliothis zea* (Boddie), and the southern green stinkbug (SGSB), *Nezara viridula* (L). The SICM model divides VBC developmental stages into six distinct periods which are both temperature- and insect-related individual dependents. The length

[2]Note that e' is proportional to h'.

of time required for a VBC larva to develop from one stage to the next varies with temperature and also varies among VBC in different development stages raised at identical temperatures. Insects move through age categories within a given growth stage until they have accumulated a sufficient number of physiological days to advance to the next development stage (*14*, *23*). One physiological day is defined as the proportion of development completed in 1 day at 26.7°C.

The CEW population model developed by Stinner and others uses a variation in development time for a given temperature to estimate the change in generations (*20*). The model indicates the value of variables daily and calculates stage populations; damage to seeds, pods, and foliage for each developmental stage; and mortality from all sources. The third insect model describing SGSB is based on the work of Rudd and incorporates emergence functions to develop probability distributions for SGSB progression through development stages (*19*).

The pesticide tactics component simulates the effect of specific insecticides on individual development stages of each of the three insects including residual effectiveness over time. The insecticides most commonly used against defoliating soybean pests in the Southeast (VBC, CEW) contain permethrin. The permethrin group of insecticides provides up to a 98-percent immediate knockdown efficiency and residual effectiveness for up to 30 days after application. Methyl parathion is recommended to combat late season infestations of pod- and seed-feeding insects (SGSB, CEW), and furnishes up to a 95-percent knockdown efficiency on the day of application with little or no residual control action.

The economic component provides for net returns above variable costs as a measure of success of a chosen management strategy. Gross returns are calculated as soybean price in dollars per bushel times seed weight in bushels per acre. Costs are categorized as variable production costs other than insect control and irrigation costs, variable irrigation costs, variable pesticide costs, and a fixed cost for scouting. Table 1 shows variable production costs. Variable production costs, C_m, in dollars per acre excluding irrigation and insect control costs are calculated as:

$$C_m = 111.50 + (2.98P_g + 9.20P_d)1.15, \tag{5}$$

where P_g and P_d denote price per gallon of gasoline and diesel fuel, respectively. Equation 5 is derived from a northern Florida soybean cost-of-production budget prepared by Boggess. Variable irrigation costs per acre, C_i, are expressed as:

$$C_i = I_t[5.834 - 0.101x + 0.0067x^2 + 3.5(P_d - 1.20)], \tag{6}$$

Table 1—Variable production costs included in the SICM model

Source	Cost/unit[1]
Cost of field application of pesticides	$3.08/acre/application
Cost of employing an insect pest scout for a weekly field survey for the entire production season	$2.75/acre/season
Gasoline	98 cents/gallon
Diesel fuel	98 cents/gallon

[1]Costs reflect end of 1984 season conditions in southern Georgia.
Source: Farm Economics Information Center, University of Georgia, Athens.

where I_t denotes total seasonal irrigation (cm) and x represents the amount of irrigation per application (cm) (*6*). Variable costs of pest control in dollars per acre are calculated by multiplying the number of applications per acre by the sum of chemical and application costs per acre.

The simulator was calibrated to produce Georgia Coastal Plain soil-type conditions and was driven by 9 years of weather data (1975-83), including temperature, rainfall, radiation, and pan evaporation rate collected at the Coastal Plain Experiment Station, Tifton, GA. Insect populations and crop status are recorded daily by the simulation routine. The insect population is monitored at 7-day intervals to mimic typical soybean-scouting practices. Pest control decision stages occur when insect populations reach damage threshold levels. A simulated control is then carried out to reduce insect populations in the crop according to insecticide effectiveness ratings.

The modeling procedure describes the interaction of irrigation and IPM as two interrelated technologies. Irrigation is specified to maintain a soil water content level which alleviates most water stress incurred by the plant and maintains a turgor threshold. The total package of IPM consists of strict compliance to Georgia's Cooperative Extension IPM recommendations, which include treatment for foliage-feeding insects when defoliation in the plant stand reaches 30 percent prior to full bloom. After full bloom and up through full pod-fill, the control threshold drops to 15-percent defoliation to protect the nutritive abilities of the leaf canopy. After full pod-fill, chemical control is recommended if defoliating pressure causes 25-percent leaf canopy loss.

Hatcher and others reported producer deviations, or what may be termed use of subsets of an IPM package (*9*). Their data indicate that producers enrolled in a Georgia IPM extension program adhered to extension recommendations 69 percent of the time thresholds were reached. When a recommendation to apply a chemical control was followed, producers applied an insecticide in a timely manner 41 percent of the time. However, 59 percent of producers who followed the

treating recommendation applied an insecticide up to 7 days post-threshold, 3 days after the cooperative extension service's recommended last day of economic advantage.

The SICM model determined the effect of employing the total package of IPM, that is, following extension guidelines closely through the season, as well as a subset of the package (partially adopting), conditional on possessing irrigation. Data documenting the degree of specific insect infestations and dates when the influx occurred during 1972-84 were available from the Coastal Plan Experiment Station, Department of Entomology, Tifton, GA (*21*). The data include observations for the three insects modeled in SICM. Fifteen insect infestation and influx timing patterns as well as probability of occurrence for VBC, CEW, and SGSB, were developed from the data to describe the general nature of pest dynamics during those years. For instance, the combined probability of a light intensity VBC, CEW, and SGSB adult influx was 7 percent. A heavy and late influx of VBC combined with light intensity and expected inflights of CEW and SGSB adults had an 11-percent chance of occurring.

The simulator was run under dryland and irrigated conditions for each of the 15 insect infestation and timing patterns for each weather year under the assumption that a producer employs the total package of IPM technology. Under this deterministic approach, 270 iterations of SICM were required (15 insect patterns times 9 weather years times 2 water access options, dryland and irrigated).

We modeled producers' partial adoption of IPM by using a pseudorandom number generator to model compliance and then timeliness of threshold adherence. We performed 30 iterations of each of the 270 combinations of insect populations and weather data years, resulting in 8,100 runs of SICM. When an extension guideline population threshold was exceeded in the simulation, a random number was generated to determine whether IPM extension guidelines would be followed (random number ≤ 0.6900). When extension recommendations were followed, we used a second random number to determine when the model would apply a control up to 7 days post-threshold. When guidelines were not followed, the model enacted a control application on a predetermined calendar date (August 15) if the threshold was reached prior to this date. A threshold reached after the predetermined calendar date resulted in no control for defoliating insects. This process was repeated later in the season to determine adherence to threshold guidelines to control pod- and seed-feeding insects. Depending on the series of random numbers generated, the scenarios were ontime control, late control, predetermined calender application (Sept. 10), or no control for late-season insect pests. The expected value of net returns from these simulation runs represented producers' expected profits when following a partial adoption strategy. Yearly results were combined with the probability of any particular insect infestation pattern to derive overall summary statistics.

Results

Table 2 summarizes the simulation output for the IPM technology levels under dryland and irrigation technology conditions. Mean-variance (EV) analysis, in which the relative magnitude of these two distribution moments describing, in this case, a pest control-water access regime compared with an alternative regime, was unable to distinguish dominance between total and partial IPM under dryland production. The EV criteria indicate, however, that partial IPM dominates for the irrigation technology, probably because of the heartiness of the plant stand under irrigation and its resultant ability to resist yield-reducing insect damage with less insecticide. Total IPM generally incurs greater variable costs than a partial adoption strategy, decreasing net returns. In contrast, Gini mean difference (EG) (*24*, *22*) and expected value analysis indicate that total adoption of IPM under dryland

Table 2—Net returns, Gini mean, and dominance results for technology combinations

Technologies	Annual net returns/acre: Expected net profit	Annual net returns/acre: Variance	Gini mean difference	Dominance[1]: EV	Dominance[1]: EG	Dominance[1]: SSD	Dominance[1]: SDWRF
Dryland:							
Total IPM	58.98	8962.44	23.22	0	Total	0	Partial $r > 0.0011$[2]
Partial IPM	57.62	8653.42	21.95				
Irrigated:							
Total IPM	193.10	825.18	8.43	Partial	Partial	Partial	Partial $r > 0$[2]
Partial IPM	198.38	807.03	8.65				

[1]EV is expected value.
EG is Gini mean difference analysis.
SSD is second-degree stochastic dominance analysis.
SDWRF is stochastic dominance with respect to function.
[2]r denotes the Arrow-Pratt risk aversion coefficient, and 0 indicates that neither distribution dominates.

technology dominates, whereas the reverse is true with irrigation. Expected value and EG decisional criteria assume risk neutrality or weak risk aversion, respectively. Thus, risk neutrality or weak aversion indicate that differing levels of an applied prior technology will influence the effectiveness of a new technology, and hence, degree of adoption; an increase in α, (the introduction of irrigation) results in a (IPM) declining in importance in terms of strict adherence.

Employing the total IPM package under irrigated conditions proved inferior to adopting a partial IPM regime. This probably results from extension IPM recommendations being tailored to a dryland production technology, which is the dominant production method in Georgia. One possible hypothesis for this result is that partial adoption of IPM in conjunction with irrigation provides for an augmented information base as producers incorporate prior pest management experience along with select extension recommendations in determining a modified control program.

Considering risk preference, results indicate that as risk aversion increases, partial adoption tends to dominate under a dryland technology. Second-degree stochastic dominance (SSD) leads to indeterminate results and stochastic dominance with respect to a function (SDWRF), in which uncertain choices are defined by upper and lower bounds on an absolute risk-aversion coefficient. This implies that only strongly risk-averse producers will partially adopt IPM under dryland conditions (*15*). Producers in other risk categories would be more willing to adopt a total IPM package under dryland conditions. Obviously, if a new technology increases risk, the level of adoption will decline as the degree of risk aversion increases. Partial IPM, with irrigation, however, dominates total IPM even with risk-neutral preferences. Therefore, risk aversion does not totally account for partial adoption under irrigation. Other variables, including socioeconomic characteristics and the success of previous technology adoption, will influence current adoption practices.

Conclusion

The empirical results lend support to the hypothesis that variations in the use of existing technologies cannot be ignored when the extent of technology adoption is being investigated. The results indicate that the degree of new technology adoption under differing technology bases may coincide with strong risk preferences, but that risk may not be the overriding element. Our results suggest that strongly risk-averse producers with dryland technology may only partially adopt IPM. We suspect that producers using irrigation recognize its influence in significantly decreasing the variation in yield and returns and, hence, diminishing the effectiveness of total IPM adoption, and would select partial adoption. Thus, producers adopt the complete IPM package or subsets of the package depending to some degree on risk preferences and the level and complexity of production technologies currently in use. Providing new technology information to producers should involve presentation of a complete technology "package" as well as appropriate modifications, or partial packages, to fit neatly into the producers' current production practices.

Our results indicate that observations of varying adoption rates and methods among producers may be explained by differing technology bases or other factors as well as risk preferences. This conclusion supports the general view emerging in the literature that the riskiness characteristic is not the overriding element in the IPM adoption decision, and may be overemphasized in other adoption literature as well.

References

1. Antle, J.M. "Incorporating Risk in Production Analysis," *American Journal of Agricultural Economics*. Vol. 65, 1983, pp. 1,099-106.

2. Boggess, W.G. "Farm Budget Number 117232340 141 1, Irrigated Soybeans, North Florida." University of Florida, Gainesville, 1981.

3. Byerlee, D., and E.H. de Polanco. "Farmers' Stepwise Adoption of Technological Packages: Evidence from the Mexican Altiplano," *American Journal of Agricultural Economics*. Vol. 68, 1986, pp. 519-27.

4. Caswell, M., and D. Zilberman. "The Effects of Well Depth and Land Quality on the Choice of Irrigation Technology," *American Journal of Agricultural Economics*. Vol. 68, 1986, pp. 798-811.

5. Clay, E.J. "Equity and Productivity Effects of a Package of Technical Innovations and Changes in Social Institutions: Tubewells, Tractors and High-Yielding Varieties," *Indian Journal of Agricultural Economics*. Vol. 30, 1975, pp. 74-87.

6. D'Almeda, P.J., G.D. Lynne, and A.G. Smajstrla. "A Users Manual for the Farm Systems Lab Irrigation Cost Generator." University of Florida Economic Information Report No. 157, University of Florida, Gainesville, 1982.

7. Farm Economics Information Center, Department of Agricultural Economics, College of Agriculture University of Georgia, Athens. Personal communication.

8. Feder, G., R.E. Just, and D. Zilberman. "Adoption of Agricultural Innovations in Developing

Countries: A Survey," *Economic Development and Cultural Change*. Vol. 33, 1985, pp. 255-98.

9. Hatcher, J.E., M.E. Wetzstein, and G.K. Douce. *An Economic Evaluation of Integrated Pest Management for Cotton, Peanuts, and Soybeans in Georgia*. University of Georgia Agricultural Experiment Station Research Bulletin 318, Nov. 1984.

10. Jenson, R. "Adoption and Diffusion of an Innovation of Uncertain Profitability," *Journal of Economic Theory*. Vol. 27, 1982, pp. 182-93.

11. Johnson, S.R., and G.C. Rausser. "Systems Analysis and Simulation: A Survey of Applications in Agricultural and Resource Economics," *A Survey of Agricultural Economics Literature*. Vol. II. G.G. Judge, R.H. Day, S.R. Johnson, G.C. Rausser, and L.R. Martin (eds.). Minneapolis: University of Minnesota Press, 1977.

12. Just, R.E., and R.D. Pope. "Stochastic Specification of Production Functions and Economic Implications," *Journal of Econometrics*. Vol. 7, 1978, pp. 67-86.

13. Kennedy, J.O.S. *Dynamic Programming: Applications to Agriculture and Natural Resources*. New York: Elsevier Applied Science Publishers, 1986.

14. Leppla, N.C., T.R. Ashley, R.A. Guys, and G.D. Butler. "Laboratory Life History of the Velvetbean Caterpillar," *Annals of Entomological Society of America*. Vol. 70, 1977, pp. 217-20.

15. Meyer, J. "Second Degree Stochastic Dominance with Respect to a Function," *International Economic Review*. Vol. 18, No. 2, 1977, pp. 477-87.

16. Musser, W.N., M.E. Wetzstein, S.Y. Reece, P.E. Varca, D.M. Edwards, and G.K. Douce. "Beliefs of Farmers and Adoption of Integrated Pest Management," *Agricultural Economics Research*. Vol. 38, 1986, pp. 34-44.

17. Pingali, P.L., and G.A. Carlson. "Human Capital, Adjustments in Subjective Probabilities, and the Demand for Pest Controls," *American Journal of Agricultural Economics*. Vol. 67, 1985, pp. 853-61.

18. Rahm, M.R., and W.E. Huffman. "The Adoption of Reduced Tillage: The Role of Human Capital and Other Variables," *American Journal of Agricultural Economics*. Vol. 66, 1984, pp. 405-13.

19. Rudd, W.G. "Population Modeling for Pest Management Studies," *Mathematical Bioscience*. Vol. 26, 1975, pp. 283-302.

20. Stinner, R.E., R.L. Rabbs, and J.R. Bradley, Jr. "Population Dynamics of *Heliothis zea* (Boddie) and *H. virescens* (F) in North Carolina: A Simulation Model," *Environmental Entomology*. Vol. 3, 1974, pp. 163-68.

21. Todd, J.W., S.H. Suber, N. Minton, T. Reed, M. Beach, and S. Thompson. "Development of Integrated Pest Management Systems in Soybeans." Annual reports for 1972-83. University of Georgia, Agricultural Experiment Station, Tifton.

22. Wetzstein, M.E., P.I. Szmedra, R.W. McClendon, D.M. Edwards. "Efficiency Criteria and Risk Aversion: An Empirical Evaluation," *Southern Journal of Agricultural Economics*. Vol. 20, 1988, pp. 171-78.

23. Wilkerson, G.G., J.W. Mishoe, J.W. Jones, J.L. Stimac, D.P. Swaney, and W.G. Boggess. "SICM; Florida Soybean Integrated Crop Management Model. Model Description and User's Guide." Version 4.2. Report AGE 83-1. Dept of Agr. Eng. Inst. Food and Agricultural Sci. University of Florida, Gainesville, Nov. 1983.

24. Yitzhaki, S. "Stochastic Dominance, Mean Variance, and Gini's Mean Difference," *American Economic Review*. Vol. 72, 1982, pp. 178-85.

Rural Retail Sales and Consumer Expenditure Functions

David Henderson

Abstract. *An elasticity of retail sales with respect to farm, manufacturing, and transfer income is estimated for three community sizes and seven types of retail businesses. The results indicate the aggregate marginal propensity to consume retail goods locally decreases in the smallest communities and increases in the largest communities when rural income increases. The estimated elasticity ranged from minus 4.9 to positive 5.6 across the seven business types and three sources of income.*

Keywords. *Elasticity, rural retail distribution system, community hierarchy.*

Discussion about the economic vitality of rural communities and how to measure it has risen anew since the farm crisis of the early 1980's, the Conservation Reserve Program of the 1985 Farm Act, the drought of 1988, and the forthcoming rural development provision of the 1990 Farm Bill. Most local impact models use one county or a set of counties as the impact area to quantify the effect of changes (*9*).[1] Using the county as a spatial unit of observation has been a traditional necessity because most annual local economic data are collected and reported at the county level. County-level economic estimates, however, are not the best community indicators because not all communities within a county are homogeneous.

Different communities within a county generally will have a different mix of economic functions, and some will be more integrated with the outside economy than others (*10*). Central place theory explains a hierarchy of communities where the number of retail functions performed at a community increases as the size (order) of a community increases (*6*). The theory predicts that the market relationship between retail business activity and rural demand will vary across communities in the hierarchy (*11*).

Larson's discussion of statistical inferences from spatially aggregated data alludes to two extreme solutions (*8*). One completely ignores the statistical problems of spatial aggregation, and the other solution uses only primary data collected from observations on individuals. This article's statistical framework settles between the two extremes. I decomposed the spatially aggregated county unit of observation into meaningful economic area units represented by individual Minnesota communities and developed a model that estimates the elasticity of retail sales by community size and type of retail businesses with respect to three sources of disposable rural income.

A Theoretical Model of Community Retail Sales

Westward expansion of agriculture spawned most existing rural communities. Retail businesses in each community were able to capture most local consumer expenditures because transportation difficulties impeded local consumers from shopping in more distant communities. Today's realistic view of the rural community sees it as part of a larger retail distribution system which includes numerous different size (order) communities. Rural consumers shop more frequently at more distant larger communities in the contemporary retail distribution system and no longer spend all of their disposable income in the nearest small community (*2*).

The contemporary rural retail distribution system unifies the individual communities through the maintenance of retail services that the smaller communities, as separate individual units, cannot support. Given that different rural communities have different agglomerations of businesses in them and form a regional distribution system for retail goods, individual community market area boundaries are in a state of constant flux and are less well defined then in the past. The consumer choice of what size community to shop at may depend more on the composition of family consumption than how close the nearest community is (*1*).

The neoclassical model's retail demand for an individual rural consumer is expressed as a function which maximizes utility subject to price and income levels, or analogously, as an indirect utility function in a cost minimization framework. Neither the direct utility function nor the indirect utility function is readily observable, but an equivalent expenditure function is. The consumer duality theorem states that the Marshallian demand function at the optimal level of utility equals the indirect utility function at given price and income levels and provides the theoretical link to the empirical expenditure function (*12*):

$$U^*[X(P\ Y\ ;\#)] = V(P^*Y^*); \qquad (1)$$

$$[V(P^*Y^*)]^{-1} = E(P\ U^*), \qquad (2)$$

Henderson is an agricultural economist with the Agriculture and Rural Economy Division, ERS.

[1]Italicized numbers in parentheses cite sources listed in the References section at the end of this article.

where U refers to utility, P to a vector of prices, Y to a vector of incomes, * to the level of the variable or function at the optimal solution (quantity desired), and # to tastes and other endogenous arguments.

Roy's identity formalizes the relationship between the unobservable utility function, which underlies the ordinary demand function, and income, which underlies the observable expenditure function (*12*). The optimal solution of the expenditure function with respect to changes in income is identical to the optimum solution derived from the demand function (*3*). The identity provides a rationale for empirically estimating demand for consumption goods without requiring direct information about the utility function of individual rural consumers:[2]

$$U^* \equiv \delta V(P^*Y^*)/\delta Y_j$$
$$+ [(\delta V(P^*Y^*)/\delta Pi)(\delta E(P^*Y^*)/\delta Yj)],$$

$$U^* \equiv -\delta V(P^*Y^*)/\delta Y_j$$
$$= [(\delta V(P^*Y^*)/\delta Pi)(\delta E(P^*Y^*)/\delta Yj),$$

$$U^* \equiv -\delta V(P^*Y^*)/\delta Yj)/(\delta V(P^*Y^*)/\delta Pi)$$
$$= \delta E(P^*Y^*)/\delta Y_j,$$
$$= \delta X(P^*Y^*)/\delta Y_j. \qquad (3)$$

The identity empirically requires that the amount of disposable income ($\Sigma_j(Y)$) spent by a consumer at businesses in a community equals the consumer's expenditures ($\Sigma_j E(P^*Y^*)$) at businesses in a community, which, in turn, equal the total retail sales ($\Sigma_n(P^*_h X_h)$) by retail businesses to the consumer in a community during a given time period:

$$\Sigma_j Y \equiv \Sigma_j E(P^*Y^*) \equiv \Sigma_n(P^*_h X_h), \qquad (4)$$

where n is the number of retail goods, j an element of rural disposable income, and Y (Σ_j) total disposable income spent in the community by the rural consumer. The Marshallian demand function generalized to n commodities and aggregated across all individuals obtains a continuous market demand function for each good (*3*). With prices constant and rural income as an independent identical distribution, the continuous community budget constraint is the horizontal summation of all individual consumer budget constraints (*12*):

$$\Sigma_i\Sigma_j\Sigma_k Y \equiv \Sigma_i\Sigma_j\Sigma_k E(P^*Y^*) \equiv \Sigma_i\Sigma_n\Sigma_k(P^*_h X_h), \qquad (5)$$

where k is the number of rural consumers and i refers to the communities where the consumers purchase goods.

[2]Community utility functions traditionally have been derived from an aggregation of individual indifference curves (*11*).

The identity does not constrain consumers to spending all of their total disposable income in any one nested community market but instead allows them to spend their disposable income at any community market in the hierarchy during a given time period. The optimum solution to the theoretical community demand function with respect to income is identical to the optimal solution of the community expenditure function with respect to income:

$$\delta\Sigma_i\Sigma_j\Sigma_k E(P^*Y^*)/\delta\Sigma Y = \delta\Sigma_i\Sigma_n\Sigma_k X(P^*Y^*)/\delta\Sigma Y. \qquad (6)$$

Both the community demand function and the aggregate community budget constraint are linear and continuous so the result for the individual consumer from equation 3 generalizes to the community market of equation 6. Changes in the level of income shift the aggregate budget constraint, cause movement along the expenditure function, and alter retail sales in a community.

Data and Model Specification

The Minnesota Department of Revenue furnished the retail sales data. The data covered 1979-86 and included annual gross retail sales by community and by Standard Industrial Classification code. The data contained information for 79 communities, of which 2 averaged 219 retail businesses per year over the period, 10 averaged 101, and the remaining 67 averaged 40. The 79 communities were divided into three mutually exclusive groups based on the number of retail establishments to identify the community hierarchy of the region.[3] Data for the independent variables were collected from the Census of Agriculture, Census of Population, and the Bureau of Economic Analysis of the Department of Commerce.

The empirical community demand function must have a variable that accounts for the mutual attraction of a larger number of retail businesses being located in the bigger communities (*4*, *6*). The community hierarchy variable must be endogenous because the larger set of goods offered in the bigger communities affects rural consumers by inducing them to spend a higher proportion of their disposable income in the larger communities than in the smaller communities (*1*, *10*). The community demand function, with a community hierarchy, was identified as follows:

$$\Sigma_n\Sigma_k D(x) = f(P\ Y\ H\ ;\#), \qquad (7)$$

where D is aggregate demand summed across all goods (n) sold in community i and all consumers (k) who purchase goods in community i, x is aggregate

[3]The hierarchy was constructed so the variance of the independent variable was approximately equal across the three community size groups. Other stratifications that did not equalize the variances increased heteroskedasticity in the estimates.

retail sales in community i, P is a vector of prices, Y is a vector of disposable incomes spent in community i, H is a variable that accounts for the community hierarchy effects of different sets of retail goods being sold (purchased) in different size communities, and # are tastes and other endogenous arguments.

Two models were specified, the first to estimate the elasticity of aggregate retail sales in communities of different sizes with respect to different sources of rural income (farm, manufacturing, transfer payments), and a second model to estimate the elasticity of retail sales by business type with respect to the basic sources of rural income by community size. In both models, equation 7 was specified as:[4]

$$C_{iht} = \alpha + \beta Y_{jt} + \beta HY_{jt} + \beta P_t + \beta CP_t + \beta FN_t + \beta OCP_t + \beta ROY_t + e_{iht}, \qquad (8)$$

where C is real retail sales (deflated by the implicit price deflator) by community (i = 1...79) and retail business type (h = 1..7), α is an intercept term, β are parameters to be estimated, Y is the rural income of interest (j = farm income, or manufacturing income, or transfer payments), P is a Minnesota consumer price index, H is a dummy variable used to stratify the communities by size, CP is the population of each community, FN is the number of farms in a county, OCP is open country nonfarm population in a county, ROY is total personal income minus Y_i and minus the income from the retail sector of interest in the county in which the community was located, t refers to year (1979-86), and e is a random additive error term. The equation was specified to facilitate estimation of the elasticity of retail sales by community size with respect to different sources of basic rural income with price (P), total population (CP + OCP + FN), and all other income (ROY) intended to control for the other observable endogenous arguments.

The model estimates coefficients on farm, manufacturing, and transfer income separately because of their contribution to basic income in the rural economy of the region and because the relationship between the different income sources and retail sales may vary. Families who derive their income from farming are at a different income level and could have different tastes than families who earn income from manufacturing income or transfer payments. If the relationship between the different basic incomes and retail sales differs by community size, then changes in the income levels will have a different impact on the rural retail distribution system.

The estimated partial derivative of retail sales with respect to a rural income leads to inferences about the marginal propensity to consume retail goods locally by source of income, type of business, or size of community over the period. A positive derivative indicates that an increase in the income of interest leads to higher rural expenditures and a higher marginal propensity to consume retail goods locally. A negative derivative indicates that an increase in the income of interest leads to lower rural expenditures and a lower marginal propensity to consume retail goods locally.

The sign of the partial derivative of retail sales with respect to income at the community level reflects changes in rural expenditure patterns within the rural retail distribution system (*2*). Other things being equal, changes in rural expenditures at businesses increase or decrease total retail revenues (sales) and partially determine the profit of retail businesses in different size communities (*11*). When profit levels of retail firms change within the rural retail distribution systems, some communities become better locations for retail businesses than other communities. Over time, the retail distribution system of the area changes as the number of different types of retail businesses within the different size communities adjusts (*4*).

Estimation

A Generalized Least Squares (GLS) regression procedure was run on the cross-sectional time series data as the error could have had both heteroskedastic and autoregressive attributes. Heteroskedasticity was anticipated in the data and was minimized in the estimation and sampling procedure. The study area was constructed from contiguous counties that were homogeneous with respect to the independent variables used.[5] The construction of the hierarchy dummy variable equalized the variance of the independent variable across the three community size groups.

The observation on the dependent variable is at the community level and the observation on the independent variable is at the county level. The independent county-level observations (Minnesota Crop Reporting District 7 plus Yellow Medicine County) are variables from identical distributions. The identical distribution of the independent variables across the spatial units of observation establishes a zero covariance and independence (*7*). The sample design facilitates a special case of equivalency between the GLS (SUR) and the Ordinary Least Squares (OLS) regression techniques (*5*).

A first-order autoregressive parameter was estimated separately for each aggregate community market time series. I estimated 237 autoregressive parameters across the 79 communities and 3 income categories for

[4]A linear model was chosen over other functional forms because of its better fit.

[5]Chi-square homogeneity tests indicated approximately equal variances among the income variables across the counties, showing regional homogeneity and minimal heteroskedasticity.

the aggregate community sales function. Not all retail business types were present in all the communities, so a total of 546 autoregressive parameters were estimated across 26 representative community markets and 3 income categories for the 7 business-type sales functions.

The model allows the value of the autoregressive parameter (p) to vary from one cross-sectional unit to another. To find consistent estimates of p, I used unbiased and consistent ordinary least squares coefficients to calculate regression residuals. The estimated residuals were employed in an iterative (15 iterations) Hildreth-Lu procedure which produced maximum likelihood estimates of each autoregressive parameter. The transformation matrices (Ω) were as follows:

$$\Omega = \begin{bmatrix} \sigma^2 V_1 \; 0 \dots\dots\dots 0 & & \\ 0^1 \; \sigma^2 2V_2 \dots\dots\dots 0 & & \\ . & . & . \\ 0 & 0 \dots\dots\dots & \sigma^2_n Vn, \end{bmatrix} \qquad (8)$$

$$\text{where } V_i = \begin{bmatrix} 1 & p_i & p^2 i \dots p_i^{T-1} \\ p_i & 1 & p_i \dots p_i^{T-2} \\ . & . & . \\ p_i^{T-1} & p_i^{T-2} & p_i^{T-3} \dots 1, \end{bmatrix}$$

and

$$P_i = \frac{\Sigma e_{it} e_{i,t-1}}{\Sigma e^2_{i,t-1}} \qquad (t = 2, 3, \dots T).$$

Results

The following sections present estimations of the equations and retail sales elasticities, followed by an explanation of the relationship between the estimated elasticities and the rural retail distribution system.

Equation Estimates

Table 1 shows the estimated equations for total retail sales for the three different sources of rural income. I had expected positive signs for all three incomes for the largest communities and negative coefficients for the smallest communities. The significance of the estimates indicates that the relationships between different rural incomes and aggregate retail sales can be efficiently estimated across different size communities.

Tables 2 through 8 show the estimated equations for each of the seven business types. I had expected both positive and negative signs on farm, manufacturing, and transfer income. The significance of the coefficients and high R^2 indicates the relationship between different rural incomes and retail sales can be efficiently estimated for different business types across different size communities.

Table 1—Estimated aggregate community retail sales equations by rural income source

Income source	Farm	Manufacturing	Transfer
Constant	−1,187,871	−828,563	−2,390,634
	(.5227)	(.6263)	(.2691)
Size of community:			
Large	65.16	90.79	138.41
	(.0010)	(.0001)	(.0001)
Mid-sized	4.76	−50.87	−63.88
	(.0001)	(.0001)	(.0001)
Small	−58.54	−91.96	−138.57
	(.0097)	(.0001)	(.0001)
Control variables:			
Residual income	−38.13	−32.98	−33.33
	(.0925)	(.1343)	(.1343)
Farm numbers	810.75	−157.91	796.32
	(.0005)	(.8603)	(.3030)
Price	−10,117.45	−12,171.12	3,928.67
	(.0153)	(.2276)	(.7718)
Community population	8,628.73	8,606.35	8,182.54
	(.0001)	(.0001)	(.0001)
Residual population	347.32	405.49	419.12
	(.1217)	(.0653)	(.0616)
R^2	.9774	.9776	.9782

Probable values are in parentheses. Rather than the author arbitrarily deciding the rejection region, the reader should exercise discretionary judgment in acceptance or rejection of the two-tailed null hypothesis of $\beta = 0$.

Table 2—Estimated SIC 52 (Building Materials) retail sales equations by rural income source

Income source	Farm	Manufacturing	Transfer
Constant	3,544,746	3,385,763	1,742,043
	(.0001)	(.0052)	(.2610)
Size of community:			
Large	−11.41	27.01	−76.52
	(.0001)	(.0001)	(.0001)
Mid-sized	−.68.37	−44.93	−137.96
	(.0001)	(.0001)	(.0001)
Small	−72.26	−52.71	−137.51
	(.0001)	(.0001)	(.0001)
Control variables:			
Residual income	−51.49	−46.22	−53.28
	(.0002)	(.0015)	(.0002)
Price	−18,609.51	−16,199.38	3,770.94
	(.0052)	(.0120)	(.6840)
Farm numbers	−1416.33	−1406.85	−1665.43
	(.0019)	(.0271)	(.0046)
Community population	1,229.71	1,072.98	1,288.32
	(.0001)	(.0001)	(.0001)
Residual population	585.85	509.09	712.63
	(.0002)	(.0010)	(.0001)
R^2	.8987	.8986	.8972

Probable values are in parentheses. Rather than the author arbitrarily deciding the rejection region, the reader should exercise discretionary judgment in acceptance or rejection of the two-tailed null hypothesis of $\beta = 0$.

Table 3—Estimated SIC 53 (General Merchandise) retail sales equations by rural income source

Income source	Farm	Manufacturing	Transfer
Constant	−5,587,110	−6,140,654	−6,201,648
	(.0189)	(.0249)	(.0391)
Size of community:			
Large	26.18	−2.15	−36.88
	(.0945)	(.1102)	(.0070)
Mid-sized	−18.03	−63.54	−139.88
	(.0945)	(.2870)	(.0070)
Control variables:			
Residual income	8.14	−14.69	−32.77
	(.8266)	(.6942)	(.1343)
Farm numbers	2.02	861.41	−27.93
	(.9989)	(.6219)	(.9840)
Price	11,611.12	11,525.03	25,205.65
	(.4590)	(.4529)	(.1743)
Community population	1,003.04	1,153.74	1,048.05
	(.0308)	(.0097)	(.0155)
Residual population	445.24	438.046	819.13
	(.2278)	(.2270)	(.0337)
R^2	.9145	.9148	.9226

Probable values are in parentheses. Rather than the author arbitrarily deciding the rejection region, the reader should exercise discretionary judgment in acceptance or rejection of the two-tailed null hypothesis of $\beta = 0$.

Table 4—Estimated SIC 54 (Grocery Stores) retail sales equations by rural income source

Income source	Farm	Manufacturing	Transfer
Constant	3,963,824	−2,322,447	23,030,665
	(.1621)	(.3146)	(.0001)
Size of community:			
Large	53.27	−165.36	942.69
	(.7058)	(.0016)	(.0001)
Mid-sized	61.72	−52.75	1,012.44
	(.0174)	(.0007)	(.0005)
Small	58.28	4242.52	1,210.91
	(.1085)	(.0002)	(.0001)
Control variables:			
Residual income	44.29	34.92	−23.49
	(.0561)	(.0476)	(.1011)
Price	10,011.00	−3,287.84	−119,798.90
	(.4388)	(.7672)	(.0001)
Farm numbers	8,812,19	4,147.71	411.63
	(.0001)	(.0184)	(.7610)
Community population	1,222.01	2,072.98	1,571.83
	(.0002)	(.0001)	(.0001)
Residual population	−1,136,90	−667.53	−2,864.90
	(.0001)	(.0024)	(.0001)
R^2	.9709	.9828	.9908

Probable values are in parentheses. Rather than the author arbitrarily deciding the rejection region, the reader should exercise discretionary judgment in acceptance or rejection of the two-tailed null hypothesis of $\beta = 0$.

Table 5—Estimated SIC 55 (Automotive Stores) retail sales equations by rural income source

Income source	Farm	Manufacturing	Transfer
Constant	5,058,931	1,886,383	−2,664,268
	(.0584)	(.4941)	(.4375)
Size of community:			
Large	−289.48	−122.37	−509.80
	(.0001)	(.0012)	(.0001)
Mid-sized	−75.39	17.02	−395.17
	(.0001)	(.0012)	(.0052)
Small	−148.77	−155.14	−496.37
	(.0081)	(.0001)	(.0003)
Control variables:			
Residual income	−95.45	−148.36	−65.87
	(.0106)	(.0005)	(.1017)
Price	−12,492.19	17,602.63	45,620.40
	(.4102)	(.2773)	(.0398)
Farm numbers	−4,426.88	−3,737.01	−3,504.69
	(.0031)	(.0423)	(.0309)
Community population	3,763.13	3,834.73	3,751.03
	(.0001)	(.0001)	(.0001)
Residual population	1,004.00	1,219.07	1,246.25
	(.0114)	(.0052)	(.0043)
R^2	.9177	.9012	.9071

Probable values are in parentheses. Rather than the author arbitrarily deciding the rejection region, the reader should exercise discretionary judgment in acceptance or rejection of the two-tailed null hypothesis of $\beta = 0$.

Table 6—Estimated SIC 56 (Apparel Stores) retail sales equations by rural income source

Income source	Farm	Manufacturing	Transfer
Constant	3,398,875	2,985,463	2,799,896
	(.0001)	(.0016)	(.0106)
Size of community:			
Large	−42.98	−35.28	−30.06
	(.0001)	(.1097)	(.0007)
Mid-sized	−15.86	−15.72	16.84
	(.0001)	(.1490)	(.0007)
Control variables:			
Residual income	−16.51	−16.42	−4.24
	(.0895)	(.1653)	(.7104)
Farm numbers	1,497.33	−1,969.21	−1,685.59
	(.0003)	(.0008)	(.0006)
Price	−18,545.00	−15,660.07	−19,497.76
	(.0001)	(.0036)	(.0045)
Community population	801.14	813.37	805.04
	(.0001)	(.0001)	(.0001)
Residual population	167.21	181.17	35.11
	(.1045)	(.1383)	(.7718)
R^2	.9393	.9122	.9243

Probable values are in parentheses. Rather than the author arbitrarily deciding the rejection region, the reader should exercise discretionary judgment in acceptance or rejection of the two-tailed null hypothesis of $\beta = 0$.

Table 7—Estimated SIC 57 (Furniture Stores) retail sales equations by rural income source

Income source	Farm	Manufacturing	Transfer
Constant	1,284,581	1,316,021	8,460,080
	(.0939)	(.0769)	(.3644)
Size of community:			
Large	57.54	21.72	51.94
	(.0001)	(.0169)	(.0004)
Mid-sized	11.94	−15.81	2.16
	(.0001)	(.0002)	(.0001)
Small	4.18	−7.41	6.28
	(.0001)	(.0169)	(.0004)
Control variables:			
Residual income	19.69	31.12	13.28
	(.0375)	(.0024)	(.1644)
Price	−14,532.36	−17,714.94	−11,784.90
	(.0008)	(.0001)	(.0401)
Farm numbers	1,893.81	1,516.44	1,916.63
	(.0001)	(.0008)	(.0001)
Community population	64.32	66.28	85.22
	(.5476)	(.5611)	(.4501)
Residual population	−242.31	−265.41	−176.71
	(.0189)	(.0111)	(.0043)
R^2	.8949	.8876	.8962

Probable values are in parentheses. Rather than the author arbitrarily deciding the rejection region, the reader should exercise discretionary judgment in acceptance or rejection of the two-tailed null hypothesis of $\beta = 0$.

Table 8—Estimated SIC 58 (Eating Places) retail sales equations by rural income source

Income source	Farm	Manufacturing	Transfer
Constant	−247,361	−267,130	−1,420,581
	(.6846)	(.6523)	(.0446)
Size of community:			
Large	29.63	31.65	1.17
	(.0001)	(.0316)	(.0001)
Mid-sized	1.02	−5.72	−45.63
	(.0001)	(.0001)	(.0001)
Small	−2.37	−10.21	−56.77
	(.0001)	(.0002)	(.0001)
Control variables:			
Residual income	−45.76	13.79	10.89
	(.2210)	(.0720)	(.0453)
Price	−808.73	−1,238.90	8,376.50
	(.8005)	(.6962)	(.0453)
Farm numbers	−145.76	−335.79	93.82
	(.6115)	(.3030)	(.7381)
Community population	554.85	501.44	488.67
	(.0001)	(.0001)	(.0001)
Residual population	−46.32	−59.98	9.97
	(.5482)	(.8968)	(.8968)
R^2	.9549	.9548	.8876

Probable values are in parentheses. Rather than the author arbitrarily deciding the rejection region, the reader should exercise discretionary judgment in acceptance or rejection of the two-tailed null hypothesis of $\beta = 0$.

Elasticity Estimates

The elasticities indicate that the aggregate community sales function tends to be more inelastic than the individual business-type sales functions (table 9). The aggregate community sales function elasticities are more inelastic because they represent an average estimate of the individual business-type elasticities. The average aggregate community elasticity contains both positive and negative elasticities for particular retail business types, which when averaged together, tends to weight the aggregate community elasticity toward zero.

The estimated elasticities, by income source, varied by both community size and business type. The varying elasticities across retail business type, when source of income and size of community are held constant, reflect different marginal propensities to consume retail goods locally, by business type. The varying elasticities across community size, when source of income and type of business are held constant, reflect different marginal propensities to consume retail goods locally, by community size. The varying elasticities across income source, when size of community and type of business are held constant, reflect different marginal propensities to consume retail goods locally, by income source.

The estimated derivatives, which determine the sign of the elasticity, were positive for all three income sources for the aggregate community sales function in the two largest communities. The estimated derivatives, conversely, were negative for all three income sources for the aggregate community sales function in the smallest communities. This implies that when income increases, the aggregate marginal propensity to consume retail goods locally declines in the smallest communities and increases in the largest communities. This is consistent with both theory and previous research, which shows retailing activity in smaller communities continually declining and regional growth centers emerging in other parts of rural America (*2*, *4*).

Dynamic central place theory explains changes in the number of different business functions in communities of different size when the profit level of the firm changes (*11*). Within this contemporary class of models, rural community retail businesses represent a tertiary sector supplying consumer goods to a rural population (*6*). Other things being equal, changes in rural income are a shock that alters consumer expenditures, retail business revenue (sales), and profit levels of retail businesses.

In the long run, as rural expenditures and the level of retail sales change for particular business types in the different size communities, some businesses will

become more profitable and others less profitable. The analysis indicates that, on average, an increase in rural income increases consumer expenditures and retail sales (revenues), causes positive economic profits, and induces retail businesses to enter the larger community markets. The same increase in rural income, averaged across business type, decreases consumer expenditures and retail revenues (sales), causes real economic losses, and prompts retail firms to exit the smaller community markets. Over the long run, this dynamic process influences adjustments in the central-place hierarchy and partially determines which goods are offered in the different size communities of the rural retail distribution system.

Table 10 shows the distribution of retail business type, by community size, for the sample area. The percentages represent the average chance of finding a particular type of retail business in a community of a certain size in the sample hierarchy during the period. Previous research indicates that the relative frequencies of the retail business types, by community size, will change in the long run (*4*).

Consider the relative frequencies of SIC 58 (Eating Places) in table 10 and the estimated elasticities for SIC 58 in table 9. The estimated elasticities are negative for all income sources for the smallest communities. The estimated elasticities, however, are positive for all three income sources for the largest communities. This implies that if these sources of rural income increase in the future rural expenditures, retail sales, total revenues, and profits will continue to decrease for SIC 58 in the lowest level of the hierarchy and continue to increase in the highest level of the hierarchy. This implies that the proportion of retail establishments of this particular type will decrease in the smallest communities and increase in the largest communities in the long run.

Further examination of the tables reveals there are many similar tradeoffs between changes in rural income and the future distribution of the samples' central-place hierarchy. Most of the tradeoffs occur within the same business type between communities of different sizes. Over time, some type of retail businesses, such as SIC 53 (General Merchandise), could completely disappear from the lowest level of the hierarchy and be present only in the larger communities.

Table 9—Estimated income elasticities for retail sales

Item	Standard Industrial Classification code[1]							
	SIC 52 sales	SIC 53 sales	SIC 54 sales	SIC 55 sales	SIC 56 sales	SIC 57 sales	SIC 58 sales	Total sales
Largest communities (2):								
Farm	−0.03*	0.06**	0.01	−0.33*	−0.25*	0.33*	0.11*	0.02*
Manufacturing	.09*	−.01	−.02*	−.16*	−.24	.15*	.14*	.01*
Transfer	−.32*	−.12*	.13*	−.82*	−.25*	.43*	.01*	.04*
Mid-sized communities (10):								
Farm	−.56*	−.13**	.25*	−.17*	−.14*	.28*	.01*	.01*
Manufacturing	−.19*	−.17	−.07*	.02*	−.15*	−.19*	−.04*	−.02*
Transfer	−1.17*	−.96*	3.49*	−.87*	.31*	.05*	−.62*	−.05*
Smallest communities (67):								
Farm	−1.34*		.28**	−1.55*		.32*	−.13*	−.53*
Manufacturing	−.92*		.63*	−.65*		−.47*	−.34*	−.46*
Transfer	−3.32*		5.63*	−4.91*		.68*−	−3.28*	−1.33*

[1]Refer to *Standard Industrial Classification Manual*, Executive Office of the President, Office of Management and Budget, 1987, for a complete description of retail activities included in the analysis. Significance levels: (two-tailed test of $\beta = 0$) * = 5 percent, ** = 10 percent. Elasticities could not be estimated for the small communities in the case of SIC 53 or 56 because the sales data were not available.

Table 10—Distribution of retail businesses by community order

Item	Standard Industrial Classification code							Community frequency
	SIC 52	SIC 53	SIC 54	SIC 55	SIC 56	SIC 57	SIC 58	
				Percent				
Community order:[1]								
Trade centers	6	3	5	13	8	11	13	59
Satellite centers	4	2	3	6	3	4	6	28
Smallest centers	2	0	2	3	2	2	2	13
Sector frequency	12	5	10	22	13	17	21	100

[1]Distribution based on a representative sample of 26 communities that had four or more businesses in an SIC code for every year between 1979 and 1986.

Conclusions and Implications

The elasticity of retail sales with respect to rural income varies by type of retail business, source of income, and size of community. The varying elasticity of retail sales based on rural income by type of business and size of community implies that the marginal propensity to consume retail goods locally varies by source of income, type of business, and size of community. The results demonstrate that different rural development strategies that change the various rural income sources will result in different adjustments in the rural retail distribution system.

The estimates point to some retail business types having a better chance of success in some sizes of communities than in others. This information could help both to decrease the failure rate for new small retail enterprises and to increase the efficiency of investment in Main Street retail businesses in rural communities. Increasing the efficiency of investment and stabilizing rural retail businesses could enhance rural planning efforts and help provide a more stable general economic environment for public services in rural areas.

References

1. Fothingham, A.S. "A New Set of Spatial Interaction Models: The Theory of Competing Destinations," *Environment and Planning*. Vol. 15, 1983, pp. 15-36.

2. Henderson, David, Luther Tweeten, and Dean Schriener. "Intraregional Development: Agriculture and Nodal Adjustment in Oklahoma's Southern High Plains," *Regional Science Perspectives*. Vol. 18(2), 1988, pp. 44-59.

3. Henderson, James, and Richard Quandt. *Microeconomic Theory: A Mathematical Approach*. New York: McGraw-Hill Co., 1980.

4. Johansen, H., and G. Fuguitt. *The Changing Rural Village in America: Demographic and Economic Trends Since 1950*. Cambridge, MA: Ballinger Publishing Co., 1984.

5. Johnston, J. *Econometric Methods*. New York: McGraw Hill Co., 1984.

6. King, Leslie J. *Central Place Theory*. Beverly Hills, CA: Sage Publications, 1984.

7. Larson, Harold J. *Introduction to Probability Theory and Statistical Inference*. New York: John Wiley & Son, 1982.

8. Larson, Robert. "The Invalidity of Modifiable Areal Unit Randomization," *Professional Geographer*. Vol. 38(4), 1986, pp. 369-74.

9. Nelson, Marlys, and Lloyd Bender. *Choosing Among Local Impact Models*. RDRR-63. U.S. Dept. Agr., Econ. Res. Serv., Nov. 1986.

10. Shaffer, Ron. *Community Economics: Structure and Change in Smaller Communities*. Ames: Iowa State University Press, 1989.

11. White, R. "Dynamic Central Place Theory," *Geographical Analysis*. Vol. IX, 1977, pp. 226-43.

12. Varian, Hal. *Microeconomic Analysis*. New York: W.W. Norton & Co., 1984.

Benefit-Cost Analysis as a Dialogue

Benefit-Cost Analysis: A Political Economy Approach. *By A. Allan Schmid. Boulder, CO: Westview Press, 1989, 354 pages, $29.50 (hardcover).*

Reviewed by David Letson

Do economists talk to themselves? Allan Schmid thinks so. He says that being more social would make us more responsive and give us greater audience. The problem is that benefit-cost analysis (BCA) as currently practiced is rather one-sided; the economist's monologue should be a public sector dialogue. Otherwise, the economist usurps the politician's role. The debate is not a new one, of course. T.W. Hutchinson, for example, warned that welfare economics could not offer "policies without politics."[1] BCA, after all, is only the applied arm of welfare economics. What is new here is a BCA text from an avowed institutionalist. Schmid offers an unlikely synthesis of budgetary politics and the techniques of project evaluation. The perspective is often refreshing.

BCA as practiced is not a dialogue. Schmid knows the reason why: a politician would rather the analyst work out compromises than submit to the dirty and unrewarding task himself. Openness about alternatives only helps form opposition, and choosing between them in public means disappointing someone. When explicitness will raise conflicts, obfuscation is the key. Schmid refers to this practice as "heat transfer." Acknowledgment of the practical circumstances of this practical craft is most useful. Ultimately, though, his book is a collection of analytical techniques wedded with a critique of conventional BCA. The problem is that he amasses technique without providing a suitable structure for them by linking them to the ideal of the dialogue. The result is a book that adds to the economist's tool kit of BCA techniques but falls short of its own standards.

The objective of Schmid's synthesis is to make BCA more useful. His thesis is undeniable: the usefulness of BCA is compromised when we mistake value judgments for technical questions. His argument has three themes. The first likens BCA to consumer information, which at its best is explicit and consistent. Not surprisingly his concern is with the assumptions inherent in BCA. These assumptions should bend to meet the realities of circumstance and public sentiments. He envisions BCA as an iterative dialogue between democratic voices and economists. Popularly expressed rates of discount and risk aversion preferences would allow the economist to speak more responsibly about economic policy. The second theme is the practicality of second-best theory in a process where assumptions must be flexible. His third theme insists that our work have distributive content as well: allocation and distribution are inseparable. The vision of BCA here is an ambitious one, introduced as the decisionmaking approach by Alan Peacock, Robert Sugden, and Alan Williams.[2] These arguments have conceptual appeal despite Schmid's admitted inability to describe the form this dialogue might take.

The comparison with consumer information is a good one. Assumptions do restrict the usefulness of BCA. Practitioners know how assumptions limit the focus of their analysis and ultimately the conclusions that might be drawn from it. Students' education in this area is incomplete without this sort of confrontation with the facts. He devotes a chapter, for example, to pointing out the difficulties with using market prices as opportunity costs in the presence of market power, foreign exchange fluctuations, and distortionary taxation. Schmid defines opportunity costs in the usual way but suggests the valuation of resources in alternative uses requires a policy decision: what are the policy objectives? Here Schmid raises an interesting question: why do market prices as indicators of opportunity cost rarely raise a critical eyebrow while the choice of discount rate always does? The discount rate is merely the more obvious assumption. Both are part of Schmid's dialogue.

So assumptions are important. Best to choose them carefully and spell them out clearly for the reader. Plenty of other texts already exist that make this point clearly enough. What's different here is a batch of alternative methods for use when the orthodox assumptions will not do. Schmid knows that orthodox methods will prevail in the profession until alternatives can match the power of their analytical techniques. His presentation of second-best methods is the real contribution here. Distortionary taxes, government budget constraints, and imperfectly competitive prices are the norm for Schmid. He shows how to adjust prices for the effects of taxation and market power so that these prices more closely reflect opportunity costs. Analysts given a budget, rather than allowed to determine one, can use capital rationing to

Letson is an agricultural economist with the Resources and Technology Division, ERS.

[1]T.W. Huchinson, *Positive Economics and Policy Objectives*, Cambridge, MA: Harvard University Press, 1964.

[2]Alan Peacock, "Cost-Benefit Analysis and the Political Control of Public Investment," *Cost-Benefit and Effectiveness-Studies and Analysis*, J.N. Wolfe (ed.), London: Allen and Unwin, 1973, pp. 17-29. Robert Sugden and Alan Williams, *The Principles of Practical Cost-Benefit Analysis*, Oxford: Oxford University Press, 1978.

rank projects systematically within the allotted resource limit.

But methods are only tools. To provide a methodology, a statement of what these methods have to say, Schmid needs to show the logic which justifies their use in attempting to solve a problem. H.H. Liebhafsky defines methodology as a logical defense of method.[3] Schmid does acknowledge the need for some methodological structure. He notes in passing, for example, that his emphasis on second-best theory ties in well with his dialogue. For support he cites the finding of Boadway and Bruce in their examination of second-best conditions that a social welfare function is necessary to rank projects.[4] A dialogue involving public debate could provide the important assumptions underlying this function. More of this linkage is necessary to keep the reader mindful of the author's vision of BCA. The reader does not get a sense of how these methods form an approach consistent with the dialogue he describes. Schmid's book would read more as the alternative methodology he intends and less as a critique if he could bridge the gap between vision and technique.

The third theme stresses the distributive content of BCA. Schmid claims that the book is not a criticism of BCA but only of those presentations and practices that fail to offer much in the way of systematic illumination. The reader may think otherwise. In large part, his effort is to broaden the scope of BCA. He would include more distributional considerations, such as pecuniary externalities and distributive weights. Hardly a section goes by without Schmid mentioning some distributive implication of an assumption. Most authors sell the virtues of distributive analysis but see it as something apart from allocative BCA. Schmid's motivation for extending the BCA label here is elusive. Since all acknowledge the usefulness of allocative and distributive analysis, his argument appears to be one of emphasis and semantics. It does not advance his metaphor of BCA as a dialogue.

Broadening BCA can dilute its purpose. Schmid is correct to point out that the complex impact of a project upon income distribution often shows up only as a net social gain or loss in the project evaluation. Transfers should be made explicit and should be efficiently delivered. Where some, like E.J. Mishan, would part company is on Schmid's assertion that these considerations should fall within BCA. Traditional BCA is a part of, and not a substitute for, the economic analysis of a project. While distributive analysis should be part of the economic analysis, many would argue that it should be separate from the determination of whether or not the project results in a net social gain.

Schmid targets these arguments to the classroom, where his text will compete with E.J. Mishan's, now in its fourth edition.[5] Here, Schmid is at a disadvantage. The reason, quite simply, is that students would be more likely to read Mishan's superbly written text. Even at 354 pages, Schmid's book is underdeveloped. Schmid discusses more topics and offers more citations than Mishan, and does so in fewer pages. Introductory readers will need more coddling. Mishan's chapters are shorter and more clearly written. Schmid's extra material could be a plus. But, often, Schmid ends up with a critical review of methods to which he has given sparse explanation. Like Mishan, a knowledge of intermediate micro and some calculus is presumed, but here a recollection of Mishan is also needed. The student will need to have Mishan nearby since that book often seems to be Schmid's point of departure. The books are complements rather than substitutes.

Schmid's text is not a neoclassical one, and he does trade off some formal elegance for practical detail. With an applied craft such as BCA, both types of knowledge are necessary. For the student's sake, though, the first should precede the second. To criticize or elaborate upon knowledge the student has yet to encounter is futile. On the other hand, pedagogical reliance upon the neoclassical treatment of this practical subject may not explain carefully enough the differences between the neoclassical world and the real one it mimics. Critical thinking is important to understanding BCA but should follow and build upon the fundamentals of the craft that Mishan ably provides. Schmid is a better choice as a second text than as a first one.

The synthesis of BCA techniques and budgetary politics is a legitimate contribution. The parts are available elsewhere, but the wisdom from examining the whole is not. Benefit-cost analysts provide information, and control of information is a source of political power. Since the public and its elected officials have a limited appetite for alternatives and details, exercise of this power is unavoidable. We act within our role when we produce what Schmid calls "useful" BCA, that which does not confuse technical questions and value judgments. Schmid's task in bridging the two areas is large, too much perhaps to bring off in a first edition. Some substantive and expository problems remain. The metaphor of BCA as a dialogue is compelling enough to make this a worthwhile effort though. Schmid's book is a refreshingly practical look at a practical craft and deserves consideration for the classroom.

[3] H.H. Liebhafsky, *The Nature of Price Theory*, Homewood, IL: The Dorsey Press, 1968, pp. 7-8.

[4] Robin W. Boadway and Neil Bruce, *Welfare Economics*, Oxford: Basil Blackwell, 1984.

[5] E.J. Mishan, *Cost-Benefit Analysis*, fourth edition, London: Unwin Hyman, 1988.

Technology Transfer and Agriculture: How Well Have We Done?

Transformation of International Agricultural Research and Development. *Edited by J. Lin Compton. Boulder, CO: Lynn Reinner Publishers, Inc., 1989, 236 pages, $30.*

Reviewed by Margot Anderson

This collection of nine essays written primarily by economists, sociologists, and extension experts examines the institutions and organizations that develop and transfer agricultural technology. The writers emphasize technology transfer and productivity growth in developing countries. The essays collectively discuss the components of successful programs and point out where improvements could be made. While there is little new ground explored in these nontechnical essays, they provide a good background in the problems associated with the agricultural research and technology transfer. A general underlying theme is that local conditions and the needs of technology users must be recognized in order for new technology to be developed and successfully employed. This seemingly obvious point has been overlooked frequently in many research institutions.

The collection will attract readers interested in how technology is developed and transferred and how problems of agricultural development are addressed in poorer countries. The essays are likely to appeal to those not already familiar with the problems of agricultural growth and technology transfer. More experienced readers may find that the essays do not go far enough to provide insight into how and why technology is developed and disseminated.

The collection is divided into three groups: historical perspectives, selected problems, and future challenges. The Flora and Flora essay in the first section focuses on the development and the evolution of the U.S. land grant and extension system and how these institutions have been implemented overseas. They conclude that, for many developing countries, U.S.-like institutions can be successful in creating and adopting locally useful agricultural technology. The authors stress that institutions responsible for generating and transferring agricultural technology in developing countries must emphasize serving the needs of the local community and not on imitating the U.S. system.

Eastman and Grieshop provide a narrower focus of the appropriateness of U.S. institutions in developing countries by concentrating on how U.S. institutions have been implemented in potato production in Peru. Although potato research has been well funded since the mid-1950's, potato yields have increased only slightly. The authors suggest that producers have been less willing to adopt new technology because of slow growth in domestic potato demand, relatively low prices received for staple crops compared with export crops, and poorly developed infrastructure. The authors argue that the ability to increase yields is only one step toward promoting increased productivity and that adoption may be limited or encouraged through agricultural and macroeconomic policies, land reform, and access to credit and inputs. These points deserve further discussion.

The importance of the economic and sociologic environment is frequently overlooked. Ruttan stresses this point in his essay, arguing the need to increase the social science component in international and indigenous research programs. Schuh has argued elsewhere that significant breakthroughs for many staple crops are limited and that ecologic and economic considerations are the most important factors for increases in agricultural productivity.[1]

The need to link agricultural research and technology transfer to the conditions of the local community is discussed in several essays. Compton develops, in some detail, the link between agricultural research and extension by calling for a more "dynamic" model of technology development, diffusion, and utilization that incorporates the users of innovations in the process of creating new technology. Warren examines why research and transfer institutions have long ignored subsistence farmers and how these institutions are now responding to the needs of small-scale farmers. Women's participation in agriculture, an integral component in agricultural development in many poor countries, continues to receive inadequate attention. Sachs and Caye discuss how women contribute to development and examine the types of institutional change that can facilitate women's participation in agriculture.

A theme that is not adequately addressed is the role of the private sector in developing and transferring new technology. The authors generally focus on public sector research, ignoring the incentives for private sector research and transfer. The increased role of the pri-

Anderson is an agricultural economist with the Resources and Technology Division, ERS.

[1]Edward G. Schuh, "Income and Agricultural Production in Developing Countries," *Technology and Agricultural Policy: Proceedings of a Symposium*, Washington, DC: National Academy Press, 1990.

vate sector is partially attributed to declining public sector research budgets and to government policies that motivate private sector research. In many countries, the private sector has become an important originator and marketer of agricultural innovations, particularly in seeds, pesticides, fertilizers, and machinery. Because public and private sector research institutions operate under different sets of incentives, the goals of research and transfer may be in conflict. Understanding the implications for private sector research on the supply and distribution of innovations is an important component of agricultural growth in many developing countries. Any progress in the area of international property rights under the GATT or within individual countries could increase the level of private sector research and influence the direction of research.

The essays include: (1) "An Historical Perspective on Institutional Transfer" by Cornelia Butler Flora and Jan L. Flora; (2) "Technology Development and Diffusion: Potatoes in Peru" by Clyde Eastman and James Grieshop; (3) "Communicating Scientific Knowledge" by R.D. Colle; (4) "Women in Agricultural Development" by Carolyn Sachs and Virginia Caye; (5) "The Integration of Research and Extension" by J. Lin Compton; (6) "Evolution and Transfer of the U.S. Extension System" by Everett M. Rogers; (7) "Linking Scientific and Indigenous Agricultural Systems" by D.M. Warren; (8) "The International Agricultural Research System" by Vernon W. Ruttan; (9) "Farming Systems, Research, and Extension" by Robert K. Waugh, Peter E. Hildebrand, and Chris O. Andrew.

Frontiers of Input-output Analysis. *Edited by Ronald E. Miller, Karen R. Polenske, and Adam Z. Rose. Oxford: Oxford University Press, 1989, 335 pages, $49.95.*

Reviewed by Chinkook Lee

Recent years have seen users of input-output (I/O) analysis in empirical research blessed with volumes of new books and a journal emphasizing I/O analysis. Joining this wealth of new material is this volume of selected papers from three conferences held in 1986 commemorating the 50th anniversary of input-output analysis as a new field of economics: the special session honoring Professor Wassily Leontief's contribution to the economics profession at the annual meetings of the American Economic Association held in New Orleans, Louisiana, December 27-30, 1986; the eighth International Conference on Input-Output Techniques, Sapporo, Japan, July 28-August 2, 1986, which highlighted Leontief's contribution to I/O techniques; and the North American meetings of the Regional Science Association in Columbus, Ohio, November 14-16, 1986, in a session marking the 35th anniversary of Walter Isard's application of I/O analysis to regional analysis.

"Many of these papers represent work at the frontiers while others show the broad range of theoretical and empirical input-output research being conducted today" (editor's preface). I found that there are truly some "frontiers" of I/O analysis in this book. For example, the two papers by Klein and Almon use I/O-econometric models to examine industrial impacts of U.S. macroeconomic policies. These two fields of economics, I/O analysis and econometrics, have recently begun to blend after having gone their separate ways for a considerable time. Nobel Laureate Lawrence Klein pioneered large econometric macroeconomic models and has used imbedded I/O models to account for sectoral details and Clopper Almon has developed advanced I/O-econometric forecasting models.

The System of National Accounts (SNA) and Social Accounting Matrix (SAM), described in Polenske's article, also belong to the "frontiers," in my opinion. SNA has been used by the United Nations and many nations, including the United States, since 1972. An SNA-based I/O table is calculated from two separate matrices: the make matrix (industry × commodity) for the origin of outputs and the use matrix (commodity × industry) for the use of inputs. An explicit advantage of the make-use framework is the possibility of a detailed description of secondary production. A SAM, an expansion of I/O accounts, includes distribution of the value added on institutional actors and the expenditure of the latter on final demand. SAM's form an appropriate framework for revealing the structural properties that determine growth and equity performance at different times.

"The Changing Structure of the U.S. Economy," by Blair and Wykoff, establishes its own frontiers. The U.S. economy has undergone a number of significant structural changes over the past decade, yet these changes are not readily apparent from traditional I/O measures, such as the total output multiplier. Blair and Wykoff expose these changes through trends in contribution to total value added (GNP). Whether the effects of changing final demand or changing sectoral production functions are principal factors affecting structural changes has been the subject of intensive studies in recent literature.

It was good to see again an article by Torii of Keio University, Japan. Torii has been a major contributor to the international conferences of I/O techniques, and this time he introduces tariff rates, freight, and insurance rates explicitly into international I/O analysis to examine the effects of tariff reduction in the Asia-Pacific Region. Since construction of empirical I/O tables is time consuming and costly, the accuracy and quality of data are extremely important, so the presentation of how to deal with measurement error and data is welcome. The book also focuses on recent developments in evaluating the accuracy of I/O models in a formal manner.

Parts of the book should have covered a broader range of theoretical and empirical I/O research. Recently, particularly at the ninth International Conference on Input-Output Techniques at Keszthely, Hungary, September 4-10, 1989, topics that appeared, but were not discussed in depth, are discussed extensively in this book. For example, six papers at the Hungary conference explored what to do with negative coefficients in a total requirements matrix when we use commodity technology assumption as a nation adopts an SNA accounting system.

The essays dealing with structural decomposition methods, used by many countries to examine growth and technological changes in their economies, would have benefited by covering more countries where the formal method of structural decomposition is used to analyze the changing pattern of each nation's economy. Six papers at the Ninth I/O conference dealt with this

Lee is an agricultural economist with the Agriculture and Rural Economy Division, ERS.

issue, particularly participants for countries in Eastern Europe and developing countries.

Because this volume is based on papers presented at three conferences, most articles are very short. Therefore, to understand and use the methods presented in this book, the reader may need to supplement with other references. Overall, however, this volume is a significant addition to existing I/O analysis.

Because matters influencing I/O analysis are continuously changing, I would not be surprised to see another volume of new developments in I/O analysis soon. I/O analysis has become an integral and, I hope, permanent part of the economics.

The papers include: Section I—Input-output and Econometric Models: 1. "Econometric Aspects of Input-output Analysis" by Lawrence R. Klein; 2. "Industrial Impacts of Macroeconomic Policies in the INFORUM Model" by Clopper Almon; 3. "Supply Functions in an Input-output Framework" by William Peterson.

Section II—Alternative Accounting Frameworks: 4. "Historical and New International Perspectives on Input-output Accounts" by Karen R. Polenske; 5. "Descriptive versus Analytical Make-Use Systems: Some Austrian Experiences" by Norbert Rainer; 6. "Toward an Input-output Subsystem for the Information Sector" by Reiner Staglin; 7. "Multiplier Analysis in Social Accounting and Input-output Frameworks: Evidence for Several Countries" by Solomon I. Cohen.

Section III—Extended Models and Multiplier Decompositions: 8. "Decomposition of Input-output and Economy-Wide Multipliers in a Regional Setting" by Jeffrey I. Round; 9. "The Effects of Household Disaggregation in Extended Input-output Models" by Peter W. J. Batey and Melvyn J. Weeks; 10. "Interrelational Income Distribution Multipliers for the U.S. Economy" by Adam Z. Rose and Paul Beaumont; 11. "Labor Quality and Productivity Growth in the United States: An Input-output Growth-Accounting Framework" by Edward H. Wolff and David R. Howell.

Section IV—Regional, Interregional, and International Issues: 12. "Effects of Tariff Reduction on Trade in the Asia-Pacific Region" by Yusuhiko Torii, Seung-Jin Shim, and Yutaka Akiyama; 13. "Structural Change in Interregional Input-output Models: Form and Regional Economic Development Implications" by William Beyers; 14. "Spatial Interaction and Input-output Models: A Dynamic Stochastic Multi-objective Framework" by Peter Nijkamp and Aura Reggiani.

Section V—Measurement Error and Data Scarcity: 15. "Perspectives on Probabilistic Input-output Analysis" by Randall W. Jackson and Guy R. West; 16. "Qualitative Input-output Analysis" by Ranko Bon; 17. "Error and Sensitivity Input-output Analysis: A New Approach" by Michael Sonis and Geoffrey J.D. Hewings; 18. "On The Comparative Accuracy of RPC Estimating Techniques" by Benjamin H. Stevens, George I. Treyz, and Michael L. Lahr; 19. "Trade-Off between Error and Information in the RAS Procedure" by Janusz Szyrmer.

Section VI—Measurement and Implications of Technological Change: 20. "An Input-output Approach to Analyzing the Future Economic Implications of Technological Change" by Faye Duchin; 21. "The Changing Structure of the U.S. Economy: An Input-output Analysis" by Peter D. Blair and Andrew W. Wyckoff; 22. "An Input-output Analysis of Technological Changes in the Japanese Economy: 1970-1980" by Hideo Kanemitsu and Hiroshi Ohnishi.

Evaluating the Costs and Benefits of Good Intentions

Forestry Sector Intervention: The Impacts of Public Regulation on Social Welfare. *By Roy G. Boyd and William Hyde. Ames: Iowa State University Press, 1989, 306 pages.*

Reviewed by Michael Percy

Government intervention in the forestry sector of most industrialized economies is pervasive, often well intentioned, and, more often than not, unsuccessful in achieving its stated objectives. Policies aimed at correcting market failure often exacerbate the problem and in many instances assume market failure when none exists. The magnitude, as well as the distribution, of costs and benefits that arise from government intervention in the forestry sector is often difficult to quantify. The difficulties in evaluating the impact of public sector initiatives in forestry derive as much from the complexity of the regulatory framework and data constraints as they do from the failure of investigators to adopt the appropriate methodology.

In seven case studies of the U.S. forestry sector, Boyd and Hyde tackle head-on the problems of specification and quantification in assessing the impact of government intervention on economic efficiency and income distribution. The book is an outstanding success in terms of the interest and breadth of the topics considered, the clarity of presentation, and the care exhibited in tightly integrating the analytical framework and data requirements into the topic under consideration. Each chapter is accompanied by a comprehensive set of references to the public policy issues, methodology, and data.

The authors are demanding—the book is analytical and presumes a strong background in microeconomics. It is also probably one of the best applied microeconomic texts one could use in a graduate or senior undergraduate forest economics course. The assumptions of the various models are very clearly set out, and tremendous care is taken to ensure that the corresponding econometric or quantitative analysis is consistent with the underlying model specification. Moreover, the methodology employed in each of the chapters readily generalizes to other applications. I had little difficulty in using the study in a graduate course as a framework for assessing equivalent Canadian topics. In each chapter, when reviewing the particular policy objective and mechanism of intervention, the authors highlight the salient features of the problem, such as market failure or underlying allocative and distributional considerations, and provide a generic methodology appropriate for similar classes of problems and associated government intervention.

The authors evaluate seven basic forest sector interventions by Federal and State governments. State forest practice acts, technical assistance programs, price reporting services, minimum wage and occupational safety and health regulations, the Jones Act, taxation, and public ownership of forest lands are assessed in terms of success in achieving stated objectives and the accompanying distribution of costs and benefits.

The results of the analysis are striking, confirming what other authors have found regarding the net economic benefits and distributional consequences of government intervention in the forestry sector. Space precludes a detailed review of their findings. With the exception of the price stabilization objectives of the Timber Mart-South, however, the welfare effects of government intervention are negative. For example, a case study of Virginia's forest practice act suggests that it has had no discernible effect on standing timber inventory. Nonetheless, it entails administrative costs of $150,000 per year. A case study of the Federal Forestry Incentive Program (FIP) and Technical Assistance Program (TA), which ingeniously combines a general equilibrium model with survey data for North Carolina, finds that the net social costs per year of FIP and TA are at least $947,800 and $303,000, respectively. The authors' study of public timber management and deviations from market criteria for harvest scheduling finds substantial net social welfare losses and large-scale income redistribution from consumers to producers, from returns to public lands to owners of private timber stocks, and among private timber producers in different regions. The case studies generally indicate that the distributive impact of these policy interventions is often contrary to stated objectives and to what U.S. society would view as desirable. The main beneficiaries tend to be wealthier landowners, more highly paid workers, and Canadian lumber producers while the burden falls on small private producers, lower wage employees, consumers, and Federal and State taxpayers.

It is always the prerogative of a reviewer to second-guess the choice of case studies in such a volume and to ignore the time and space constraints facing the authors. My own preference would have been to see one additional topic discussed. An analysis of the net welfare impacts and distributional consequences of trade barriers to forest products would have highlighted the important role of international trade in the domestic forestry sector. These barriers can range

Percy is a professor of economics, Department of Economics, University of Alberta, Edmonton, Alberta, Canada.

from export restrictions on logs to a tax by the Canadian Government on softwood lumber exports from certain provinces to the United States. As a consequence of the 1986 softwood lumber dispute, for example, government intervention will likely be prompted by distribution considerations. Concern over tropical deforestation and proposals for boycotts of tropical timber or the imposition of import taxes make analysis of the links between the United States and the international markets of continuing interest. The introductory chapter might have provided an overview of the salient features of the forestry sector and a context for the case studies to follow.

I highly recommend this book to anyone with a strong background in economics and who is interested in a thorough and dispassionate analysis of the variety of channels through which government intervention affects the forestry sector. This volume should become an essential feature of reading lists for senior and graduate forest economics courses.

Suggestions to Contributors for Submitting Manuscripts to *The Journal of Agricultural Economics Research*

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